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A Summary of Current Program and
Preliminary Report of Progress

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POTATO RESEARCH

of the
United States Department of Agriculture
and cooperating agencies

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This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

There is included under each problem area in the report, a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research. Also included is a brief description of related work conducted by private organizations. No details on progress of State station or industry research are included except as such work is cooperative with U.S.D.A.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last two years. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
December 1, 1962

OTHER COMMODITY AND FUNCTIONAL REPORTS

A progress report similar to this one is prepared for use by each of the following research and marketing advisory committees:

Citrus and Subtropical Fruit	Sheep and Wool
Cotton and Cottonseed	Sugar
Dairy	Tobacco
Deciduous Fruit and Tree Nut	Vegetable
Forage, Feed and Seed	Economics
Forestry	Farm Equipment and Structures
Grain	Food and Nutrition
Livestock	Food Distribution
Oilseeds and Peanut	Home Economics
Poultry	Soils, Water and Fertilizer
Rice	Transportation and Storage

Two additional reports of progress are prepared in order to make available the complete research program. They are:

Ornamentals and Other Miscellaneous Commodities
Other Research -- Cross Commodity

ORGANIZATIONAL UNIT REPORTS

All of the material in the commodity and functional reports listed above is the same as that found in the 20 division and 3 service research reports listed below.

Agricultural Research Service (ARS)

Agricultural Engineering
Animal Disease and Parasite
Animal Husbandry
Crops
Entomology
Soil and Water Conservation
Utilization -- Eastern
Utilization -- Northern
Utilization -- Southern
Utilization -- Western
Human Nutrition
Clothing and Housing
Consumer and Food Economics

Agricultural Marketing Service (AMS)

Market Quality
Transportation & Facilities

Economic Research Service (ERS)

Farm Economics
Marketing Economics
Economic & Statistical Analysis
Foreign Development and Trade
Analysis
Foreign Regional Analysis

Other Services

Farmer Cooperative Service (FCS)
Forest Service (FS)
Statistical Reporting Service (SRS)

A copy of this report or any of the others listed above may be requested from Roy Magruder, Executive Secretary, Potato Research and Marketing Advisory Committee, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

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INTRODUCTION

This report deals with research on the white or Irish potato (not sweetpotato) and covers Farm Research, Utilization Research, Marketing Research, Economic Research, and Nutrition and Consumer-Use Research of the U.S.D.A. and cooperating agencies. Only a brief description of the related work of the State Experiment Stations and industry is included.

Under each of the Problem Areas there is a statement describing the Program of work underway and the professional man-years devoted to the major kinds of research included. The relative scope of the total research effort on potatoes is indicated by the approximate number of professional man-years employed: 69 by U.S.D.A., 76 by the State Experiment Stations, and about 230 by industry and other organizations.

A brief report of Progress and significant findings for U.S.D.A. and cooperative programs is given for each phase of the research program.

A considerable amount of basic cross-commodity and functional research that will supply new knowledge applicable to the potato problems is not included in this report. Such research is included in the functional reports such as "Economics," "Soils, Water and Fertilizer," and in the "Other Research" report.

Research by U.S.D.A.

The farm research comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, and crop harvesting and handling operations and equipment. This research is conducted by the Crops, Entomology and Agricultural Engineering Divisions of the Agricultural Research Service; and in fiscal year 1962 involved 27 professional man-years.

Utilization research deals with methods of preservation of these commodities through canning, drying, freezing, or combinations of these methods and also with the origination of new forms of food products or combinations of potatoes with other foods. It is also concerned with improved equipment and processes. The work is done by the Eastern Utilization Research and Development Division, Wyndmoor, Pennsylvania; by the Western Utilization Research and Development Division at Albany, California; under contracts with foreign country laboratories; and in cooperation with the industry and other organizations mentioned under Program for each research area. In fiscal year 1962, the work involved about 20 professional man-years.

Marketing research involves the physical and biological aspects of assembly, packaging, transporting, storing and distribution from the time the product leaves the farm until it reaches the ultimate consumer. The work reported herein is conducted by the Market Quality and Transportation and Facilities Research Divisions of the Agricultural Marketing Service and utilized 15 professional man-years in fiscal year 1962.

Economic research is concerned with marketing costs, margins and efficiency; market potential, supply and demand; outlook and situation; and improving marketing through research with farmer cooperatives. The work reported herein is done by the Economic and Statistical Analysis and the Marketing Economics Research Divisions of the Economic Research Service; by the Standards and Research Division of the Statistical Reporting Service; and by the Marketing Division of the Farmer Cooperative Service. Approximately 5 professional man-years were devoted to this work in fiscal year 1962.

Nutrition and consumer-use research pertains to composition and nutritive value; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions. This work is done by the Divisions of Human Nutrition Research and Consumer and Food Economics Research of the Agricultural Research Service, and in fiscal year 1962 involved 1.5 professional man-years.

Research by State Experiment Stations

There is included under each Problem Area a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research.

Consolidating this information for the entire field of interest, we find that in fiscal year 1962 a total of 76.3 professional man-years were spent by the State Agricultural Experiment Stations on potato research.

Potato research in 1962 was in progress in 41 of the 53 State Agricultural Experiment Stations. Studies underway were carried out by research workers in Departments of Horticulture or Agronomy, Agricultural Engineering, Agricultural Economics, Entomology, Plant Pathology, Food Technology, and Home Economics. Potato research at the State Agricultural Experiment Stations in 1962 included 3.8 man-years on the agricultural engineering phases of crop harvesting operations and equipment, and building for farm storage of potatoes; 47.9 man-years on potato culture, breeding, diseases and variety evaluation; 7.2 man-years on human nutrition and consumer-use research; and 7.8 man-years

on market quality research. In addition, considerable related research was conducted on problems which could not readily be identified with specific commodities such as potatoes. This research included work on weed control, nematode control, crop introduction and evaluation; marketing economics; supply, demand, and price analysis; and improving marketing operations through research with farmer cooperatives.

No details on progress of State station research are included in this report except as such work is cooperative with U.S.D.A.

Research by Industry and Other Organizations

The 230 professional man-years estimated as industry's participation in research on potatoes are employed primarily by food processors and distributors, chemical and fertilizer companies, manufacturers of materials handling systems (over half the total is in these categories) food industry and trade associations, food container and equipment suppliers, package and container manufacturers, market research institutes and corporations, seed suppliers and growers.

A number of food processing companies and wholesale and retail distributors are presently conducting research in various phases of products and process development in frozen, canned, and dried potato products. These studies cover a wide field directed toward the securing of patents or secret processes that can be exploited rather quickly to the best interests of each company.

The canning, freezing and dehydrating industries each maintain an association with a technical staff and either do research in their own laboratories or support research at U.S.D.A. laboratories, universities and other organizations. Some of their research is of a basic nature but most of it is of an applied nature and the results are made available in trade and scientific journals.

Allied industries and suppliers to the food processing industry maintain excellent laboratories and large research staffs to provide technical information to the industry. Most of their research is of a trouble-shooting nature although many valuable contributions to the store of basic knowledge have been made by this group.

Marketing equipment and facility manufacturers also make sizeable contributions to research on the development of equipment for handling potatoes on the farm, into and out of packing houses, transportation vehicle, wholesale distribution center and in the retail establishment as well as research on the containers in which they are moved and on the transportation vehicles from which they move from one point in the distribution channel to another.

Chemical and fertilizer companies are significant factors in research on the development of new materials or combinations of materials to produce more efficiently, high quality potatoes through better nutrition of the growing plant, control of diseases, insects, nematodes, weeds, killing of tops, skin color intensification and protective waxes.

Market research institutes and others in marketing economics research are largely concerned with research in consumer preference, market potentials, and interregional and intermarket competition. The results are available only to the purchaser.

Several of the seed certification associations as well as large private seed producers expend considerable time and money on varietal adaptation experiments and disease tolerance readings that are so necessary to determine the acceptability of standard varieties and the new varieties that appear at frequent intervals from the potato breeders; Federal, State and private.

It is very difficult to estimate the contribution of growers to our overall research effort on potatoes. Certainly, in the field of production his help is indispensable for most of the laboratory research results must finally be confirmed by field experiments. The grower cooperates with the U.S.D.A., State Experiment Stations and suppliers of many materials and equipment; usually without compensation except for the experience and knowledge gained.

Industry cannot be expected to conduct basic work which is remote from its profit objectives. However, basic research done by the Department and States will be utilized by industrial research laboratories in the further development of improved products and equipment. Industry's cooperation in supporting research on potatoes in the form of grants, gifts or loans of materials, equipment and facilities at Federal and State stations has contributed greatly to its success.

No details on progress of industry research are included in this report except as such work is cooperative with U.S.D.A.

Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

Sterility Method of Insect Control. A new concept in controlling insects and other pests has been developed which may contribute to the solution of some major insect problems. The method involves the release of sterile insects for their own destruction. The mass production and release of screwworm flies made sterile by gamma radiation resulted in the elimination of this important livestock pest from the Southeast.

A similar and more complex program based on the same principle is now underway in the Southwest. In addition, the utilization of sterile insects is being intensively investigated as an aid to the control or eradication of other major pests, including tropical fruit flies, boll weevil, pink bollworm, sugarcane borer, codling moth, tobacco hornworm, and other pests. An important advance in research on the sterility method has been the development of several chemicals which produce sterility in insects with less damage to the insects than that caused by radiation. The availability of such chemicals also offers the possibility of discovering ways to induce sterility in the natural insect population, thus obviating the necessity of rearing and releasing insects sterilized by radiation to achieve control.

Potato Flakes. Production of potato flakes, a form of dehydrated mashed potatoes, is now carried out in 13 factories located in the principal potato growing areas. The factories have a total capacity of 60 million pounds of product, equivalent to 7 million bushels of potatoes. This development is one of several credited with reversing the downward trend in per capita potato consumption, to the benefit of potato growers.

Sprout Inhibitors and Storage Temperature for Potatoes. Potatoes stored at 40° or lower, a temperature required to prevent sprouting, are often not suitable for potato chips or french fries. The development of methods for using certain chemicals as sprout inhibitors together with the discovery that most potatoes will retain good processing qualities if stored at 50° to 55° F. has provided good quality potatoes for processing over a long period each year. This work has helped to extend the market for potatoes used for processing.

An Economic Study of the U. S. Potato Industry. The serious economic problem of sharply fluctuating farm prices and income resulting from a highly inelastic demand and variations in output, and the problem of general overproduction, which tends to depress the average level of prices and income are delineated in a report entitled, An Economic Study of the United States Potato Industry, Agricultural Economics Report No. 6. Per capita consumption of potatoes, after declining for 40 or more years, leveled off in the 1950's, with increased processing and stepped-up merchandising of both fresh and processed products. Several possible approaches are presented for achieving more stable and more equitable prices and income to growers in the future.

Consumer Reaction to Instant Potato Flakes. Another survey undertaken to measure consumer reaction to instant potato flakes indicated that the product had considerable appeal to consumers and could be successfully marketed if proper promotional and merchandizing efforts were employed. As a result of this research, a number of companies are now producing flakes for commercial use; the product has proved successful and is now sold throughout the country. The importance of this project

was also recognized in another manner; it received an award from the Washington chapter of the American Marketing Association as an outstanding contribution to the field of agricultural research.

I. FARM RESEARCH

POTATO CULTURE, BREEDING, DISEASES AND VARIETY EVALUATION Crops Research Division, ARS

Problem. Potatoes are grown in all 50 States and are planted and harvested every month of the year, thereby creating a need for varieties for local adaptation and specialized markets. New cultural practices necessitated by economic pressures for greater efficiency in production have tended to lower potato quality, creating a need to expand research to find ways of reversing the present trend toward lower potato quality. The trend toward potato processing (23 percent of the total crop or 40 percent of the table-stock portion of the 1960 crop was processed) has created a demand for new, more suitable varieties. The development of the food processing industry is one of the most dynamic of any agricultural industry today. There is therefore a particular need for developing basic physiological information on genetic control of enzyme systems in an effort to develop potato varieties more suitable for processing.

Potentially valuable Solanum species and released varieties are not presently fully tested. There is need to speed up this research. To raise yields and potato quality beyond present levels requires new methods of breeding, interspecific hybridization, and greater resistance to specific diseases. Potato diseases annually cause huge losses at all levels of the industry. Basic information is needed on the nature of diseases and their control and on newer methods of developing chemical, biological, and genetic controls. Increasingly serious are stem end-browning, after-cooking darkening, and internal black spot (all of which have their origin in the growing crop) and it is urgent that causes for these disorders be found. Genetic controls for insects and nematodes are needed to supplement chemical control.

USDA PROGRAM

Breeding, selecting, and testing of new varieties and seedlings for horticultural characters, storing, shipping, and culinary qualities, and local adaptation are conducted cooperatively with the States at Presque Isle, Maine, Greeley, Colo., Aberdeen, Idaho, Ames, Iowa, Baton Rouge, La., Ithaca, N. Y., Prosser, Wash., and Crystal City, Tex. In addition, testing of new seedlings is done at more than 20 additional locations in cooperation with State personnel.

Greenhouse crossing for production of true seed, for developing new varieties, and growing seedling tubers is done at Beltsville, Md., and to a lesser degree at Aberdeen, Baton Rouge, Prosser, and Greeley. Frost resistance is being developed in selections at Baton Rouge for

winter crop production. At Aberdeen and Beltsville (and to lesser degree at Greeley), stress is placed on evaluation tests for developing varieties adapted for processing. The development of insect-resistant lines is one of the major objectives of work done under cooperative agreement at Ames. In cooperation with the Rockefeller Institute in Mexico City, seedlings are being sent from Beltsville to be evaluated for resistance to severe late blight conditions of the Toluca Valley and varieties that are significantly resistant have been released. Lines resistant to wind and heat are being developed in Texas with funds partially contributed by the American Refrigerator Transit Company and the Texas Citrus and Vegetable Growers and Shippers Association.

Introduction and maintenance of Solanum stocks is done at Sturgeon Bay, Wis., at the Inter-Regional Potato Introduction Station. The production and study of Solanum tuberosum diploids (half the normal chromosome number) is done at Madison, Wis., along with interspecific hybridization of diploids. At Beltsville investigations of crossability among species and meiosis of species and species hybrids are being conducted.

Work on diseases is conducted along two main lines, control by breeding disease-resistant varieties and basic studies on the nature of the disease.

In the program of development of disease-resistant varieties, scab resistance is a major objective at all locations. The evaluation of progenies, seedling selections, and species for viruses X, A, and Y is done at Beltsville. Seedlings from Beltsville are sent to Florida for determining corky-ring-spot resistance and to New York for resistance to golden nematode. In addition, at Beltsville work is being done on the development of techniques for evaluation tests of all diseases with particular stress on leafroll and soil-borne viruses. Tests are underway to find improved methods of disease detection.

At Greeley, Colo., lines are developed that are resistant to scab and leafroll, and at Aberdeen, Idaho, and Prosser, Wash., to scab, leafroll, and verticillium wilt. Early blight tests are being initiated also at Aberdeen. At Baton Rouge, La., emphasis is placed on scab and late blight resistance, especially in red-skinned lines. At Presque Isle, Maine, disease evaluations are made for X, A, Y, leafroll, spindle tuber, ring rot, verticillium wilt, late and early blight, scab, and tuber necrosis. Disease control studies for late blight, scab, verticillium wilt and viruses are likewise conducted in Maine. Internal black spot is a major consideration in New York and Washington. Resistance to nematodes is being evaluated cooperatively in Texas and Wisconsin. Special work on evaluation of breeding lines to resistance to golden nematode is done under cooperative agreement at Ithaca, N. Y. Virus S is studied

at both Madison, Wis., (cooperatively with Wisconsin) and Greeley.

Research is conducted on the epidemiology of potato late blight to provide a scientific foundation for the experimental forecasts issued by the plant disease warning service. During 1961 epidemiological research was continued in three regions, in cooperation with the State Agricultural Experiment Stations. Headquarters, respectively, were at Raleigh, N. C.; Ames, Iowa; and Newark, Del., through August 1961, when that headquarters was transferred to University Park, Pa. Reporting of plant diseases is through the monthly "Plant Disease Reporter" (circulation 2,200), which emphasizes such matters as new records of disease occurrence, serious outbreaks and new controls.

The Federal scientific effort devoted to research in this area totals 17.1 professional man-years. Of this total, 8.3 is devoted to breeding; 6.3 to diseases; 0.1 to variety evaluation; 0.7 to introduction and evaluation; 1.4 to culture; and 0.3 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 47.9 professional man-years subdivided as follows: Breeding 18.0, diseases 13.7, variety evaluation 4.5, and culture 11.7. Emphasis is placed on the development of parental lines through inbreeding, the use of wild diploid species of Solanum as a source of desirable germ plasm and disease resistance, solving the troublesome black spot problem, and work on fundamental genetics of potato.

In industry and other private organizations, including processors, chemical companies, and private individuals, expenditures for research in 1961 are estimated at 55 professional man-years divided as follows: breeding 3, processing 12, and chemical studies 40. The objective of the breeders is to produce new high-yielding varieties that have excellent culinary and processing qualities. Processors evaluate selected seedlings and new varieties for qualities of value for specific products. The chemical companies are primarily interested in testing and evaluating new chemicals for use in disease control, sprout control, soil treatment for disease pests, color intensification of potato skin, wax treatments, and treatment of seed pieces.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE RESEARCH

A. Breeding

1. Potato-tuber greening. The tubers of several varieties and seedlings were exposed to different sources of light, including daylight,

fluorescent, and mazda, for varying periods of time to determine development of tuber-greening. Color standards were established to estimate the intensity of greening and to evaluate the effects obtained. Actual amounts of chlorophyll per unit of tuber surface area were also determined in one test.

Exposure to a combination of daylight and fluorescent light comparable to that existing in retail stores gave pronounced differences in tuber greening. Among the 5 varieties and 13 seedlings tested, the tubers of 4 seedlings (B3556-12, B4523-8, B922-3, and B922-6) developed either little or no greening when exposed for 40 to 60 days and longer. Under similar conditions the greening of Katahdin and Kennebec tubers was pronounced. Inheritance of the greening condition was studied in progenies of crosses between greening and nongreening parents. More than one factor appear to be involved in the inheritance of tuber greening and dominance is not complete.

To find an objective method of determining greening whole tubers with varying intensities of greening were subjected to light reflectance and transmittance tests in order to determine the possible usefulness of these techniques in evaluating greening intensity. Preliminary results, in cooperation with Agricultural Marketing Service, showed promise that a quantitative and nondestructive method based on the transmittance technique can be developed for rapid screening of large numbers of tubers selected for breeding purposes.

2. Potato Cytogenetics. In cooperation with Wisconsin Agricultural Experiment Station a total of 971 new haploids (plants with 2 sets of chromosomes instead of the usual 4 sets) were identified during the past year from 41 parents (7 named varieties, 30 breeding stocks, and 4 Solanum andigena selections), making a total of 1,786 identified to date. Also, 440 haploids and 15,600 hybrids between haploids (which may be considered diploids) and cultivated diploids species were grown in the field. Genetic variation was observed and selection of the most vigorous and pollen-fertile individuals was made.

The effects of boron on pollen germination on artificial media of 42 Solanum species were studied. Best results were obtained with a medium containing 20 percent sucrose plus 50 p.p.m. boric acid, held at a relative humidity of at least 95 percent. Pollen fertility in F_1 hybrids between S. tuberosum haploids and diploid tuber-bearing Solanum species varied greatly and appeared to be influenced by: (1) individual species, (2) specific haploid, or (3) the direction of the cross.

At Beltsville, Md., 33 diploid species, 5 tetraploid species, and 100 diploid hybrids were grown for cytological and crossability investigations. Of 309 combinations attempted among the diploid

species, 82 produced seed; seed was obtained from 3 tetraploid combinations. The diploid hybrids showed normal meiotic behavior with 12 bivalents at metaphase I.

3. Late Blight. Emphasis is being continued on building up field resistance in selections that will also have 1 to 4 major genes. Over 200 selections were sent to Mexico for field resistance evaluation. Resistant lines from cooperative research in Mexico are introduced. As the Mexican lines are released from the Plant Quarantine Station at Glenn Dale, Md., their genotypes are determined at Beltsville, Md., and they are then grown in Maine for selection based on horticultural characters. To date seventeen selections have been saved that have promise as parents carrying late blight resistance.

4. Spindle Tuber. In 1958, in cooperation with Maine Agricultural Experiment Station, 1,751 seedlings from 19 family lines were increased for evaluation to spindle tuber resistance. All selections were grown in two blocks of 2-hill plots in 1959. Plants in one block of plots were kept healthy and plants in the other were inoculated with spindle tuber virus by the switching technique. Tubers from the two blocks were planted side by side in 1960 and compared for spindle tuber symptoms. Four resistant clones were observed. These were reinoculated and grown again in 1961. Two clones, B4577-36 and B4513-61, out of the original 1,751 still remained free of visible symptoms. This is the first authenticated instance of probable resistance to spindle tuber to be reported.

5. Verticillium Wilt. In cooperation with Maine Agricultural Experiment Station, about 257 advanced selections or commercial varieties were tested for verticillium wilt resistance in 5-hill plots; 22 (9.0 percent) were resistant. Also, 235 seedlings from 7 family lines were retested.

6. Leafroll. In 1961, in cooperation with Maine Agricultural Experiment Station, 239 new seedlings, selected for 2 years for horticultural characters, were field-tested in 5-hill plots for leafroll resistance. Ten of these seedlings showed no leafroll infection. One of the better ones, B4783-2, from a cross between Ac. 25976 and B4095-1, is a medium-maturing, russet-skinned seedling possessing long tubers and resistance to late blight, scab, leafroll, and Y virus. Promising leafroll-resistant selections are available that have multiple-disease resistance combined with red, white, or russet skins.

7. Ring Rot. In 1960, in cooperation with the Maine Agricultural Experiment Station, 200 selections and named varieties were tested for resistance to ring rot, and 23 were found resistant. Two resistant selections, B721-29 and B3478-45, when tested for yielding ability

produced at the rate of 490 and 468 hundredweight per acre in 1961 compared to 386 hundredweight for Katahdin. Both seedlings were equal to Katahdin in solids content.

8. Net Necrosis and Stem-end Browning. In 1961, in cooperation with the Maine Agricultural Experiment Station, 116 advanced selections were tested in the field for resistance to tuber necrosis and stem-end browning. Twenty-eight, (24 percent) expressed symptoms for one or both characters. Kennebec and Katahdin were both free of net necrosis and stem-end browning but neither Mohawk nor Green Mountain, the susceptible checks, were free.

9. Golden Nematode. In cooperation with the New York Agricultural Experiment Station, 166 selections representing ten segregating family lines were tested for resistance to golden nematode. A total of 73, (23 percent) were found resistant. Seedling B4557-2, the highest yielding seedling (384 cwt./acre) in the late-maturing variety yield test, is a white-skinned seedling with known resistance to late blight, scab, and golden nematode. B4473-2 is another high-yielding, white seedling that possesses resistance to golden nematode and immunity from viruses X and A. It yielded 374 cwt. of U.S. No. 1 tubers per acre compared to 331 cwt. for Katahdin.

10. Scab. In 1961, two hundred thirty-nine advanced selections were tested in the field for scab resistance. Seventeen selections showed none to a trace of scab. Fourteen seedlings from U.S.D.A. and twelve from Minnesota were tested in scab nurseries located in Maine, Colorado, Washington, Idaho, North Dakota, and Minnesota.

11. Southern Region. Three new varieties have been released recently in cooperation with the Louisiana and Tennessee Agricultural Experiment Stations. Catoosa is a high-yielding red-skinned variety that has resistance to scab and late blight. LaRouge is a red-skinned selection similar to Red LaSoda except that the yield and scab resistance of LaRouge is higher. LaChipper is a white-skinned variety with good chipping qualities and a high degree of resistance to late blight.

12. Idaho. Selection for seedlings resistant to leafroll, verticillium wilt, and scab continued in cooperation with the Idaho Agricultural Experiment Station. Increased emphasis is placed on testing stocks for resistance to early blight which is a serious problem to growers producing potatoes under overhead irrigation in newly developed lands. Four russet selections in the 1961 yield test at Aberdeen were significantly superior to Russet Burbank in yield of U.S. No. 1 tubers and higher in resistance to verticillium wilt. Russet Burbank yielded 184 cwt. compared to 261 for A466-1, 298 for A503-42, and

253 for A597-25. Selections found highly resistant to early blight under overhead irrigation were seedlings B3948-5 and B3983-2; these also were highly resistant to late blight in the Maine field test and to leaf hopper injury in Ohio. Dates of planting and varieties tested were without significant effect on the results of planting in soil infested with Fusarium solani f. eumartii.

The Potato Selection Committee recommended that A175-7 be increased and that sufficient seed stock be furnished processing companies for large scale testing. A175-7 has large, round to oblong, russeted tubers which may become irregular some years, but which possess high resistance to verticillium wilt, medium resistance to scab, and some resistance to early blight.

13. Colorado. A total of 17,006 single-hill seedlings representing 134 families were planted at 3 locations in cooperation with the Colorado Agricultural Experiment Station. About 900 selections were made, based on horticultural characters.

14. Texas. About 22,000 seedlings from 100 crosses in 1961 were grown in single-hill units in Texas and 122 were selected for increase in Colorado in 1961. Sixty-eight lines were planted in 5-hill rows at 6 locations in 1961. Of these, 31 were considered worthy of re-testing, with 17 of these to be advanced to yield trials. Eighteen varieties and seedlings were yield-tested at 3 locations and twelve were judged promising enough to be retested in 1962. Redskin, a recent joint introduction by U.S.D.A. and Texas, produced over 327 hundredweight per acre when grown at Munday, Texas. Several selections were superior in yielding ability to the standard varieties grown in Texas.

15. Iowa. Breeding and evaluation for better varieties adaptable to conditions in the North Central States proceeded in cooperation with the Iowa Agricultural Experiment Station. Seedling Ia57410-10R, which has red skin color and scab resistance, yielded 547 cwt. of U.S. No. 1 tubers per acre compared to 365 for Irish Cobbler, the standard variety. Seedlings AIS5561-13, AIS5561-8, and AIS5561-12 had low hopperburn ratings of 1.56, 1.66, and 1.61, respectively, in contrast to a 4.50 rating for Irish Cobbler. The percent total solids of Ia57410-10R was 16.7 as compared to 18.7 for Irish Cobbler.

B. Diseases

1. Spindle Tuber Virus. The potato spindle tuber virus was transmitted to tomato by grafting and mechanical inoculation in several experiments. Tomatoes so inoculated invariably developed characteristic symptoms that differentiated this virus from others known to infect potato. On return of this virus from tomato to potato,

typical symptoms of spindle tuber were reproduced in the tubers. This represents the first demonstrated transmission of the spindle tuber virus to a host other than the cultivated potato. Symptoms in tomato were expressed within 2-6 weeks depending on the growing conditions and were sufficiently distinctive to permit the use of this plant as an indicator. Latent virus X which is present in most commercial potatoes did not interfere with the tests. Scientific studies on the nature, purification, electron microscopy and serology of the causal virus are now possible and have been initiated.

2. "Knobby Tuber" Virus. In cooperation with Maine Agricultural Experiment Station, soil-borne potato virus that produces severely stunted plants and small tubers with a knobby protrusion at each eye has been partially purified. The virus was shown to be almost completely inhibited in the plant at air temperatures above 80° F. Comparative studies with the soil-borne tobacco rattle (potato corky ring spot) virus indicated that the two viruses were not closely related.

3. Leafroll Virus. Studies on the nature of resistance in potato to the leafroll virus have confirmed the work of others that this resistance is, in part, a resistance to aphid inoculation. In some cases, however, resistance appears to be due to the physiological changes associated with symptom development. Work is proceeding on determination of the physiological basis for both types of resistance.

4. Virus Y. Cooperative studies with the Entomology Research Division were carried out in Maine on the use of virus inhibitors to control virus Y. Milk solutions applied at time of mechanical inoculation with virus Y and up to two days after inoculation were very effective in preventing infection. Tests of material from similar studies with aphid-inoculated material are not yet completed.

5. Virus X. Potato virus X was partially purified from tobacco and the purified preparations used to prepare an anti-serum. This anti-serum will be used in the screening program and in other projects.

6. Late Blight. Two hundred and seventy-two advanced breeding selections were tested for resistance to the common race as well as to the specialized races of blight in the greenhouse at Beltsville, Maryland, and in the field at Presque Isle, Maine. Of these selections tested, 198 were resistant to the common race and 37 were resistant to some combination of the specialized races as well.

Another set of 188 clones selected for field resistance to late blight and screened in Mexico were tested for field resistance at Presque Isle. In this test, 161, or 85 percent of the selections, remained free of blight throughout the season.

Late blight of tomato and potato. In the north central region studies were continued on conditions leading to epidemics of potato late blight (Phytophthora infestans). Sprout emergence from inoculated seed pieces was only 6 percent for the Cobbler variety and 70 percent for the Norland variety, compared with 97 and 98 percent, respectively, from uninoculated seed pieces, planted in an unsprayed "late blight garden" at Ames. Whereas in a similar garden at Clear Lake, Iowa, emergence was 100 percent from both inoculated and uninoculated seed of both varieties. High temperatures prevented above-ground infection in both gardens and also prevented successful infection from artificial inoculation of foliage at Ames.

Duration of dew is an important factor in the development of the late blight fungus. Dew records made by three dew-recording instruments were compared in the Ames area over an 82-day period. The Theis-Calpouzos 7-day glass plate recorder recorded 10 hours, the Taylor 24-hour glass plate recorded 11 hours, and the Wallin-Polhemus lamb-membrane instrument, 13 hours of dew. Dew deposition occurred most often at 7 p.m. The following linear regression equation was developed for predicting the number of hours of dew: $Y = .66X + 4.10$ where X = the number of hours with 90 percent or higher relative humidity. Linear regression equations were computed for eight locations in the north central region from data collected by first-order stations of the U.S. Weather Bureau. The information from these equations indicated that Weather Bureau data might be used in predicting relative humidity in potato or tomato fields.

Weekly experimental late blight forecasts based on temperature and relative humidity recorded in plant cover by hygrothermographs at weather-blight stations throughout the region were continued. Late blight appeared at different locations as predicted in some instances but not in others because of adequate control programs or perhaps because of lack of inoculum.

In the southeastern region, weather favored potato late blight throughout the season in Alabama and the mountain area of western North Carolina, and experimental forecasts accurately predicted incidence. Elsewhere, the disease was unimportant. Potential severity of late blight in the mountain area of North Carolina in the absence of forecasts and timely spray application was demonstrated by the estimated 45 to 50 percent reduction in yield of marketable tubers in the unsprayed "blight garden" at Hendersonville.

In the northeastern region, potato late blight did not develop in unsprayed "blight gardens" in Rhode Island and Delaware. Emergence from inoculated seed pieces was less than 50 percent, however, as compared with 80 percent or more from healthy seed pieces. Experimental weekly late blight forecasts, based principally on temperature and rainfall data, again proved accurate more times than forecasts based on hygrothermograph records of temperature and relative humidity of 90 percent or more. Forecasts based on temperature and 75 percent relative humidity (Beaumont method) were not accurate in the one location (in Maine) where this method was tried.

The Plant Disease Reporter and the Plant Disease Warning Service.

The Crops Research Division issues the monthly Plant Disease Reporter to provide for quick dissemination of results of plant pathological research and of important new information concerning plant disease problems. Volume 45, 1961, contained 980 pages and was sent to some 2,200 agricultural institutions, libraries, and individual plant pathologists in the United States and other countries. A summary of Reporter articles on chemical control of plant diseases is prepared each month for the "Listening Post" section of the trade journal Agricultural Chemicals.

The warning letters (Plant Disease Situation Report) sent to co-operators of the warning service report seasonal spread of potato and tomato late blight, tobacco blue mold, cucurbit downy mildew, and lima bean downy mildew, and call attention to other crop disease situations that might require careful watching.

7. Virus Y. About 311 advanced breeding selections were tested for field resistance to aphid inoculation with virus Y at Presque Isle. Of the clones tested, 180 showed positive symptoms in the field. The remaining clones will be tested in the greenhouse at Beltsville.

8. Virus A. Approximately 265 advanced selections were tested for resistance to aphid inoculation with virus A at Presque Isle. Only 30 selections showed positive symptoms in the field. The remainder will be tested in the greenhouse at Beltsville.

9. "Haploids". Thirty-eight "haploid" (2n) clones of Solanum tuberosum derived from 5 potato varieties in the U.S.D.A.-Wisconsin cooperative project were screened for susceptibility to late blight and to viruses A, Y, X, and leafroll. Ten clones were found to be resistant to the common race of blight. All haploids tested were found to be susceptible to viruses X, Y, and leafroll. Twenty-five of the 38 clones were apparently resistant to virus A.

C. Variety Evaluation

1. New Variety Releases. Ona is a new potato variety, resistant to late blight, scab, verticillium wilt, and mild mosaic, released with the Florida Agricultural Experiment Station. Its tubers are medium oblong in shape, have a smooth, white skin and shallow eyes. It has shown good chipping qualities at harvest time and at intervals after storage and reconditioning over a period of several months. Ona yields more than Katahdin when grown in Maine and more than Sebago when grown in Florida. Arenac and Emmet have latent mosaic immunity, late blight and scab resistance, and the maturity of Katahdin, and were released in cooperation with the Michigan and Iowa Agricultural Experiment Stations. Arenac, a shallow-eyed, round and smooth-tubered variety, yields very well and reconditions very well after storage for chipping. Emmet has slightly oblong tubers similar to Sebago. It has average solids content, heavy tuber-set per plant, and yields well if the soil fertility and moisture are adequate. LaRouge and LaChipper are described previously.

2. Outstanding Seedlings. Several seedlings were outstanding in yielding ability and total solids content in 1961. The leafroll-resistant seedlings, B3802-15, B4123-10, and B4491-2 produced total yields per acre of 470 hundredweight, 456 hundredweight, and 446 hundredweight, compared to 386 hundredweight for Katahdin. Also, B3802-15 with 19.7 percent solids and B4491-2 with 20.1 percent exceeded that of Katahdin with 18.6 percent. Other seedlings with multiple-disease resistance that yielded as high or higher than Katahdin were B3478-45 with resistance to ring rot and virus Y, B3570-5 with resistance to leafroll, virus X, and virus Y, and B2894-24 with resistance to late blight, scab, virus A, and ring rot.

3. Potato Introductions. One hundred and fifteen new stocks were received in cooperation with the Plant Introduction Investigations of the New Crops Research Branch in 1961 from Argentina, Bolivia, Canada, Chile, Colombia, England, Finland, Germany, Mexico, Netherlands, New Zealand, Norway, Peru, Spain, and Sweden. A good increase of seed and tubers in 1961 was obtained by propagation under screen, which has proven an economical and efficient method.

Shipments of seeds and tubers were made to 20 States and 20 foreign countries, and consisted of 236 seed samples and 1,389 tuber samples. The evaluation of stocks continues for resistance to Southern bacterial wilt, intermediate late blight resistance to race 1,2,3,4, resistance to leafroll, and resistance to frost injury being found in different species. S. penellii, a non-tuber bearing species, has been successfully hybridized with the common tomato.

D. Culture

1. Quality Evaluation of Seedlings. All seedlings and standard check varieties grown in the early-, medium-, and late-variety evaluation tests were compared for yielding ability, U.S. No. 1 grade percentages, total solids, and chipping quality immediately after harvest and at intervals of 60 days after storage and reconditioning. Most of the selections made acceptable chips after harvesting, but unacceptable after 38° F. storage and reconditioning. Only three varieties, B3172-13, F4713, and Kennebec produced acceptable chips after harvest and also after all 5 dates of removal from storage for frying, which extended from October 1, 1960 to July 21, 1961. Length of sprouts on stored tubers was recorded after 10 months' storage at 38° F. Lengths varied among selections from 0.5 to 3.5 inches. The purpose here is to select seedlings with the necessary horticultural characteristics that also will store and recondition over a period of 10 months well enough to make satisfactory chips or French fries.

Cooperative tests in Colorado on dates of planting and harvesting, seed size, and spacing, and performance of new vs. old varieties were continued. The 4-year average yields per acre of Kennebec and Blanca were highest for the medium planting date, (May 16-20) and the yields of Russet Rural and Katahdin were greatest for the early-planting date, (May 1-4). Kennebec and Blanca also produced the largest 4-year mean yields per acre on the medium harvesting date (Sept. 15-22); Russet Rural and Katahdin had the highest mean yields at late harvesting (Oct. 7-12). In the seed size and spacing test the large whole seed weighing 0.2 lb. and 7-inch spacing between seed pieces produced the greatest yields for all 3 varieties in 1961.

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WEED AND NEMATODE CONTROL
Crops Research Division, ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. The losses caused by weeds can be reduced by finding more effective chemical, biological, mechanical, cultural and combination methods of weed control. Improved weed control methods will facilitate farm mechanization, increase production efficiency, and improve the efficiency of the use of human and land resources in agriculture.

Plant-parasitic nematodes occur in all soils used for growing of crop plants and attack all kinds of plants grown for food, forage, fiber, feed, or ornamental purposes. It has been long known that severity of attack by certain fungi is greatly increased if nematodes are present; and nematodes have been known to be the vectors of several plant viruses. There is a need for improvements in the methods of controlling nematodes by crop rotations, cultural practices, chemicals, and biological methods on potatoes.

USDA PROGRAM

The Federal scientific effort devoted to basic and applied research on nematodes is 23.5 professional man-years of which 0.1 is devoted to research at Madison, Wisconsin.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Information on the weed and nematode research for commodities by State Experiment Stations and industry is not available. For a summary statement covering all research by these agencies on weed control, see pages 240 and 241; and on nematode control, see page 276, in the Crops Research Division report.

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SOIL AND WATER MANAGEMENT AND CONSERVATION
Soil and Water Conservation Research Div., ARS

Problem. The importance of soil and water conservation in the nation's agriculture can hardly be overestimated. Without these natural resources there would be no agriculture - no crops - no food - no fibers--the nation's very existence is dependent on its soil and water resources. The development of improved tillage, crop residue management, fertilization, drainage and irrigation practices requires not only a knowledge of soil and climatic factors, but also widely varying moisture, temperature and nutrient requirements for establishment and growth of different crops.

Each crop and each physiographic area presents specific problems on soil and water management and conservation. For some crops the problem is excessive moisture at seeding. For other crops, adequate moisture must be provided at seeding. High soil temperatures are critical for some crops, whereas low soil temperatures are the major problem for other crops. For legumes, proper inoculation may be a problem. Consumptive use of water, water use efficiency and proper timing of moisture and fertilizer applications need further study for various crops. In studying these various factors, different crops are used as tools to measure soil and water research responses.

USDA PROGRAM

The Soil and Water Conservation Research Division has a continuing program doing basic and applied research and employing 17 disciplines to increase knowledge in all phases of soil and water management and watershed engineering. The total professional man-years involves 416 trained and specialized workers. Potatoes are only one of many test crops in the experimental program and Federal professional man-years are not available for specific commodities. Locations at which the various kinds of research are conducted, are given below under REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations reported .6 professional man-years on this type of research for 1961. Information on soil and water research by industry on specific commodities is not available.

A serious growth abnormality with the appearance of "fern leaf" symptoms in Russet Burbank potatoes in the Columbia Basin Irrigation Project has been diagnosed as a zinc deficiency by research conducted at Prosser, Washington. This deficiency, occurring on areas of newly leveled land, was aggravated by applications of phosphate fertilizer. The deficiency was corrected by supplementing the necessary N plus P fertilization with 10 pounds Zn per acre applied as ZnSO_4 .

Decomposition of plant residues is known to have a pronounced effect on the survival of plant pathogenic micro-organisms in soil, but not enough is known about this effect to make use of it in management practices for root disease control. In continuing attempts at Prosser, Washington, to understand these processes, it has been found that decomposition of plant residues in soil in the absence of oxygen is quickly lethal to the fungus causing the verticillium wilt disease of potatoes. Prolonged anaerobic fermentation leads to drastic reduction in the populations of soil fungi in general, suggesting that other root pathogens may be similarly destroyed. The effect appears to be due to the production of fermentation products that are fungitoxic. The controlled production of anaerobic conditions in soil may be a feasible control practice against these disease-producing soil organisms.

Other laboratory studies at Prosser, Washington, have produced mutant strains of the soil-inhabiting potato-scab organism that have high resistance to the antibiotic streptomycin yet retain their pathogenic abilities. This finding furnishes evidence that this process may occur in soil, indicating that soil treatment with fungicides may lead to the appearance of new resistant strains.

In northern Maine, heating cables and plastic mulches were used early in the season to increase the temperature under potatoes. In June and early July, soil temperatures on the plots with the heating cable were 10 to 15 degrees higher than on the control. Temperature under the plastic tended to be slightly lower than the heating cable treatments. Plants on the plots with higher temperature emerged two weeks earlier and flowered one week earlier than on the control. At harvest time tuber yields were the same for all treatments.

The length of the growing season affected potato quality but had little effect on yields. Early planted potatoes had a significantly higher specific gravity and ascorbic acid content than the late planted potatoes.

An experiment was designed to measure erosion and runoff losses from potato fields. The treatments are natural soil, rocks removed, rocks crushed, fallow, and a rotation of potatoes, oats and sod.

Nine of seventy-eight storms contributed to more than 75 percent of the soil loss. The soil factor "K" for the universal soil loss equation was calculated to be 0.37 tons/acre. For these nine storms, an average of 57.5 percent of the rainfall was lost as runoff. During five of these storms better than 70 percent of the rainfall was collected as runoff. This was due to the high moisture content throughout the season.

Soil losses from plots where rocks were removed were significantly higher than from the natural or crushed rock treatments. This followed the same trend observed in 1960. Higher water losses were also measured where the rocks were removed. Soil loss from the rotation plots was 32 percent of the soil lost from the continuous potato treatment.

In north central North Dakota the effect of nitrogen and phosphorus fertilization on crop yields under irrigation was evaluated in a non-legume rotation (barley, corn, potatoes) and in a legume rotation (barley, alfalfa, alfalfa, alfalfa, corn, potatoes) on Gardena loam. In the nonlegume rotation, yields of all crops were increased by nitrogen. Phosphorus alone decreased yields of corn forage. However, with adequate nitrogen, phosphorus increased yields of barley, corn, and potatoes. In the legume rotation, the major effect of alfalfa was to supply available nitrogen.

INSECT CONTROL
Entomology Research Div., ARS

Problem. The profitable production of high-quality potatoes demanded by the consumer necessitates the control of injurious insects. Available control methods involve the use of insecticides, some of which are not adequately effective because of resistance of the insects to them. Certain insecticides may leave undesirable residues on or in potatoes. There is, therefore, continuing need for research to develop safe, effective, and economical procedures for combating potato insects. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is also need for research on the biological control of potato insects and on the evaluation of potato varieties for insect resistance.

USDA PROGRAM

A continuing program involving basic studies on the biology, ecology and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control, is conducted by the Department at Yakima, Wash.; Orono, Maine; Beltsville, Md.; and Charleston, S.C., in cooperation with the respective State Experiment Stations, the Washington Department of Agriculture, the Washington State Potato Commission and industry. Some of the work herein reported was conducted at Fort Collins, Colo. This station was closed in January 1962 and the research underway at that location consolidated with similar investigations at Yakima, Wash.

The Federal scientific effort devoted to research in this area totaled 7.5 professional man-years. Of this number 2.2 was devoted to basic biology; 2.3 to insecticidal and cultural control; 1.7 to insecticide residue determinations; 0.3 to biological control; 0.2 to insect attractants; 0.1 to varietal evaluation for insect resistance; 0.4 to insect vectors of diseases; and 0.3 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 5.6 professional man-years. Of this number 1.2 was devoted to basic biology, physiology and nutrition; 2.9 to insecticidal and cultural control; 0.3 to insecticide residues; 0.2 to varietal evaluation for insect resistance; and 1.0 to insect vectors of diseases. This work is done in 10 States, including New York, Idaho, Oregon, and Connecticut.

Industry. In addition to substantial contributions by industry on synthesis, analysis, formulation, and primary screening of insecticides for general use, which are discussed in another area, several chemical companies conduct some field tests of insecticides against insects and mites that attack potatoes. Some of these companies cooperate with growers. Others have their own experimental acreage. The results of such work are often kept confidential. Exclusive of industry's contributions through grants to and cooperative agreements with State and Federal stations, estimated annual expenditures are equivalent to approximately 4 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology

1. Aphids. After many years of study at Yakima, Wash., it has become apparent that the abundance of overwintering eggs of aphids on woody plants in the Northwest has far less bearing on aphid damage to potatoes than do the weather conditions during spring and summer. During 1961, after a mild winter conducive to aphid survival, unprecedented hot weather during June, July, and August made it impossible for damaging infestations of aphids to develop in potato fields in eastern Washington. During the mild winter of 1960-61, the potato aphid, Macrosiphum euphorbiae, the foxglove aphid, Myzus solani, and the green peach aphid M. persicae, overwintered successfully as summer non-egg-laying forms in central and southeastern Washington. Overwintering hosts of the potato-infesting aphids included alfilaria, Erodium cicutarium, a chickweed, Cerastictum sp., clasping-leaved peppergrass, Lepidium perfoliatum, flixweed, Sisymbrium amplexicaule, henbit, Lamium amplexicaule, and shepherd's-purse, Capsella bursa-pastoris. Winged spring migrants were produced on various overwintering weeds sometime prior to the appearance of potato plants in planted fields.

Aphid damage to potato plants had no important effect on the specific gravity of the tubers according to a 5-year study concluded at Orono, Maine. The tendency of the damage to reduce starch content was of no commercial significance. The work was done on Green Mountain and Katahdin varieties and results were published.

In Maine the increased use of sprout inhibitors created conditions favorable for winter survival of aphids when delayed sprouts were allowed to grow on culls discarded from summer storages. Tubers from plantings treated with sprout inhibitors before harvest, when discarded almost a year later, produce short, stubby, succulent sprouts that persist until cold weather. The foxglove aphid and the green peach aphid breed on such sprouts in abandoned cull piles and survive the winter. In contrast, culls from untreated tubers produce early season growth that either matures early or is destroyed by growers to eliminate field sources of diseases. The sparse growth on cull piles produced by discards from summer storages will also need to be destroyed to protect the potato crop from aphids.

2. Leafhoppers. Further studies on the spring movement of the six-spotted leafhopper, Macrostelus fascifrons, directed from the Fort Collins, Colo., station, showed that during May the insects moved rapidly from Texas and Oklahoma northward across the Western Great Plains. In the first week of April a survey showed no leafhoppers north of Oklahoma but by May 12 comparatively large numbers were taken in northern South Dakota. Only adult leafhoppers were collected during May in Kansas, Nebraska and South Dakota. This indicates a migratory population since the six-spotted leafhopper in this area overwinters in the egg stage. Female leafhoppers move slightly ahead of males. In western South Dakota the proportion of females to males was in the ratio of approximately 2:1, while in southwestern Nebraska and northeastern Colorado, males were present in greater numbers by about 3:1.

3. Wireworms. At Charleston, S.C., further studies on the southern potato wireworm confirm earlier indications that this insect has two generations per year and a partial third whereas other wireworms usually require from 1 to 5 years for each generation. The general biology and habits of this new pest have been determined and the information is being prepared for publication as a USDA technical bulletin. A few years ago the southern potato wireworm appeared to be a pest of potato only, and thus received its common name. Now the insect is recognized as a pest of potato, sweetpotato, carrots, beets, tobacco, and strawberry. During 1962 it was recorded for the first time damaging fields of corn. Since fairly satisfactory methods have been developed for control of this wireworm on potato, the work at Charleston is being diverted in part to a study of the insect as a pest of some of the other crops now being infested.

B. Insecticidal and Cultural Control

1. Aphids. Systemic insecticides were partially effective in reducing the spread of leaf roll at Presque Isle, Maine, in studies by the Orono station. Light applications of either of three systemic insecticides in the planting furrow controlled the aphid vectors of leaf roll so that little spread of the disease occurred. In Green Mountain potatoes--a variety rather susceptible to the disease--Di-syston granules at 0.8 pound of active ingredient per acre held the spread of leaf roll to 0.3% in treated plots as compared with 1.9% in untreated plots. Similar results were obtained with demeton at 1 and 1-3/4 pounds per acre. Phorate was somewhat less effective. In the experiments 4% of the plants were grown from leaf-roll infected tubers in order to provide a severe test of the protective value of the aphicidal treatments. The furrow-applied systemic insecticides gave near-perfect control of the aphids until the end of July, after which small numbers developed.

Also, in later experiments on Russet Burbank potatoes in Maine, Di-syston and demeton were each more effective than phorate or Menazon in controlling aphids. The materials were applied in the bottom of the planting furrow at 1 pound per acre for Di-syston and demeton, 1-3/4 pounds for phorate, and 2 pounds for Menazon. The treated plants were almost free of aphids during the early part of summer but small numbers developed in August.

At Yakima, Wash., endrin or parathion were superior to either demeton or endosulfan (Thiodan) in preventing development of net necrosis in potatoes treated for control of leaf roll vectors. In a field of Russet Burbank potatoes containing approximately 3% of chronic or tuber-borne leaf roll, 4 applications of endrin, endosulfan or demeton gave significantly better control of wingless green peach aphids than parathion when each was applied at 1 pound of active ingredient per acre per application. However, after overwintering, the tubers from the endrin and parathion treatments contained much less net necrosis than did tubers from either the endosulfan or demeton plots.

2. Wireworms. Field experiments in South Carolina confirmed previous indications that the southern potato wireworm, Conoderus falli, can be controlled in potato land by insecticides applied to the foliage of fall cover crops to kill adults of the wireworm as they collect for oviposition. Three applications of either parathion or diazinon at 1/2 pound per acre to soybean foliage in August or September reduced the adult population of the wireworm 89 to 99%.

Soil samples screened for the wireworm larvae a month after the last foliage application showed 92% control. This generation of larvae is the one chiefly responsible for damage to potatoes. Fall treatments may not be effective in protecting other crops such as sweetpotatoes.

C. Insecticide Residue Determinations

1. Phorate Residues. Residue studies in Maryland showed that a tolerance is needed to cover the registered use of phorate in potato soil applied at 3 pounds per acre to the furrow or in bands on each side of row at time of planting. Residues of phorate found in washed tubers harvested 77 days after treatment in 8 field plots ranged from 0.3 to 0.9 p.p.m. The phorate content of the potato foliage at this time was slightly higher than that of the tubers. No phorate was found in the tubers or foliage from the 4 check plots. These data substantiate results of preliminary studies in Washington in 1959. Samples from potatoes grown in different soils in Washington and Maine, however, in plots treated with phorate in 1960 and 1961 showed no appreciable residues of phorate in the mature tubers. Until an appropriate residue tolerance is established this outstanding phorate treatment cannot be recommended. No explanation has been found as to why phorate treatment occasionally leaves residues in the harvested tubers.

D. Biological Control

1. Aphids on Potatoes. The Orono, Maine, station obtained partial control of aphids on potatoes in experimental plots at Presque Isle by planting strips of untreated oats between the plots. Ladybird beetles gathered in the oats to feed on the English grain aphid and then moved to the potato plants to feed on the several species of potato-infesting aphids. The most important predators were the 5-spotted and 13-spotted ladybird beetles followed in abundance by syrphid flies and lacewing flies. A survey of parasites of potato aphids, continued for the third year, has shown that of 13 species present, Aphidius nigripes, and Praon sp. are the most important. A survey of fungus diseases of aphids showed the most common to be Entomophthora ignobilis, not previously known to occur in northeastern Maine or to be important as a pathogen on aphids.

E. Insect Attractants

1. Natural Sex Lures. Exploratory studies on the natural sex lures of insects were initiated on the southern potato wireworm at Charleston, S.C., and the six-spotted leafhopper and Colorado potato beetle at Fort Collins, Colo. There was little indication of sex lures in the leafhopper and the Colorado potato beetle but they

appeared to be present in the wireworm. Considerable progress has been made in accumulating necessary basic information on the various insects. A serious bottleneck in the work on wireworms has been the inability to separate the sexes in any stage without damage to the insects. A possible method of sexing the pupae was recently discovered and is now undergoing tests.

G. Insect Vectors of Diseases

1. Aphids and Leafhoppers. Studies at Yakima, Wash., on the six-spotted leafhopper as a vector of purple-top of potatoes (aster yellows of vegetables) indicated that maretail, Erigeron eanadensis, may be important as an overwintering host of the virus. Maretail is a common weed and in 1961 was the most frequently infected of a number of host plants of the disease. In greenhouse tests the virus was transferred from maretail to maretail by the six-spotted leafhopper. However, attempts to transfer the virus from potato to potato or to carrot, aster, endive, or Ladino clover with this insect were unsuccessful. The virus of purple-top is suspected to be one of the causes of net necrosis in potato. If this is true, both aphids and leafhoppers are indirectly responsible for net necrosis.

In other studies in Washington, the spread of leaf roll virus from rows of chronic leaf roll plants to adjacent plants started at weekly intervals from disease-free tubers, stopped abruptly during hot dry weather.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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Insecticidal and Cultural Control

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Biological Control

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CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT
Agricultural Engineering Research Div., ARS

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota. The Federal professional man-years involved are 2.0.

RELATED PROGRAM OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported 2.2 professional man-years devoted to research on potatoes, in this area, carried on in the Northeastern, North Central and Eastern regions.

Industry and other organizations conduct engineering research on equipment and methods for the harvesting of crops. Both full line and small manufacturers cooperate in USDA research through loan of equipment. Farm operators and organizations furnish land, equipment, and facilities for evaluation of experimental harvesting equipment. Much of the industrial experimental development of harvesting equipment is highly confidential and is generally not made available to public researchers. Estimates are not available for work on potato equipment.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Potato Harvesting Equipment. A three-year study of the effects of secondary pre-plant tillage practices on harvesting was completed. The experimental treatments were applied on land that had been either in summer fallow or in small grain the previous year with the stubble plowed down in the fall. An important conclusion of this study is that there is no advantage to be gained by pre-plant tillage in the spring. The results of the study of secondary pre-plant tillage practices indicated that an investigation of the effect of primary tillage (plowing or other initial soil loosening operations) upon the production of potatoes could yield valuable information. An experiment was designed for application on unplowed wheat stubble in the fall of 1960. The

results of the one-year trials showed that fall plowing deep tillage in the spring, deep tillage in the fall, or no tillage did not influence yield of potatoes, digger draft, or amount of clods.

Four-row and Six-row Potato Harvesting Operation. A new windrower was designed, constructed, and tested which makes it possible to deliver a two-row windrow to a position between two adjacent dug or undug rows and makes it possible to harvest four and six rows of potatoes with a harvester.

Spillout Losses and Blades in Potato Harvesters. A study of the location of individual tubers of Kennebec, Norland, and Pontiac varieties showed that 98 percent were located in a band 16 inches wide and 100 percent in a band 20 inches wide. Therefore, spillout with the conventional 26-inch wide harvester is due to lateral migration of tubers ahead of the apron. Studies showed that open-front style harvesters with twin rotary rod shares were entirely practical for harvesting potatoes. The amount of clods was not increased and spillout was reduced. Results also showed clod deflector shovels in combination with rotary rod shares reduced spillout losses.

Mechanical Injury of Potatoes. Instruments were developed to investigate the force and deformation relationships of potato tubers and determine whether these physical relationships could be correlated with susceptibility to injury from impacts or pressures. Preliminary results gave little encouragement that force-deformation will prove to be an easily applied measure of injury susceptibility. A series of tests were conducted to measure the electrical conductivity of potato tissue. There proved to be no conclusive correlation between these measurements and susceptibility to mechanical injury. A simple impact instrument was designed and constructed and used successfully in measuring the susceptibility to injury of potatoes. This instrument may be extremely valuable as a simple commercial instrument that can be used by potato growers to estimate the degree of injury that should be anticipated in harvesting and handling a given lot of potatoes at a given time. Production design and experimental links for harvester apron chains are being studied as to their effect on bruising potatoes. No conclusions have yet been reached.

Time Losses in Mechanical Harvesting of Potatoes. A study of amount of time lost and reason for breakdowns in harvesting potatoes mechanically showed that proper planning and management could eliminate many of the delays. The main reasons for delays were improper field layout, improper maintenance of equipment, and lack of planning for emergencies.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Potato Harvesting

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II. UTILIZATION RESEARCH AND DEVELOPMENT

PROCESSING AND PRODUCTS

Eastern Utilization Research & Development Div., ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, is becoming more and more dependent upon the development of new and improved processed products to maintain markets and to avoid recurring economic disasters. Crop perishability, supply fluctuations, and the inelasticity of demand, result in wide swings in price with even slight surpluses. In producing areas having a substantial processing industry, depressive lows are moderated by advance contracting by processors prior to harvest. However, in many important potato growing areas processing has not yet developed, and vulnerability not only still exists, but is exaggerated by the growing competition of processed potato and other competing food products. A continuing improvement in processed potato products is clearly required if processing is to expand fast enough to offset the progressive decline in use of fresh potatoes.

Lack of adequate knowledge concerning the chemical constituents, physical properties, and enzyme systems in potatoes is limiting development of new and improved processed products and processing methods. Basic research on composition is needed to provide fundamental information on which an applied research program can be systematically and effectively built. Recently developed techniques make it possible to isolate and characterize the constituents responsible for flavor, color, odor, and texture of many processed food products. Application of these techniques to potatoes and potato products should make it possible to improve the quality of present products, both freshly processed and following storage, and provide a basis for technological and engineering studies in new product development.

USDA PROGRAM - EASTERN REGION

The Department has a continuing long-term program of basic and applied chemical and engineering research on studies related to processing. The work of the EURDD, involving the services of chemists, biochemists, food technologists and chemical engineers at Wyndmoor, Pennsylvania is conducted in cooperation with the Maine Agricultural Experiment Station and several other stations, which supply potatoes of known cultural history. The chemical research program includes evaluation of the effects of variety, location of production, storage conditions and tuber solids content on potato composition with particular respect to nitrogenous constituents; principal acids and factors related to discolorations such as after-cooking discoloration. The Eastern Division's engineering and development research program seeks to improve the quality,

nutritive value and storage stability of dehydrated potato products and to develop more convenient types of dehydrated products, such as "instantized" slices that cook quickly.

The Federal (Eastern Division) scientific effort devoted to research in this area totals 13.0 professional man-years. Of this total, research on chemical composition as related to processing characteristics comprises 10.0 p.m.y. During the year, research at Wyndmoor, Pa. on potato after-cooking discoloration was terminated. Research on dehydrated potato products constitutes 2.0 p.m.y. During the year, research at Wyndmoor on development of potato flakes was completed. Research on new and improved processing technology amounts to 1.0 p.m.y.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 7.5 professional man-years divided among subheadings as follows: Chemical composition and physical properties, 4.5; new and improved food products, 1.1; new and improved processing technology, 1.9. Relationships that exist between the total solids contents, groups of constituents and individual constituents and the various quality attributes of potatoes are being determined. Basic information is sought that will be useful in improving current products and processing techniques, with attention to color and flavor problems.

Industry and other organizations conduct a considerable amount of research on the composition and properties of potatoes and on development of new products and improved processes. Basic research is confined almost entirely to a few large firms, with applied research carried out by these large companies as well as by the smaller companies and the trade institutes. While liaison is maintained to promote the flow of nonconfidential information between the Department and industry, much of the industrial research findings are not disclosed to others because of commercial advantage attached to such information. Estimated annual expenditures are equivalent to approximately 55 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition as Related to Processing

1. Nitrogenous Constituents. Analysis of many potato samples has indicated, for the most part, that no spectacular or regular changes occur during the storage season in the amounts of the amino acids present. For a given production locality, nitrogen content on the fresh weight basis of potato is nearly constant from sample lot to sample lot. Maine and New York potatoes from the 1960 crop were first surveyed for amino acid content. This was followed by 1961

crop potatoes (Katahdin, Russet Burbank, Kennebec, Red Pontiac, and Cobbler varieties) from Maine, New York, Pennsylvania, Red River Valley area, Wisconsin and Idaho. Voluminous data have been collected from extracts run through the automatic amino acid analyzer. While computations have been made up to the present only manually, results will be obtainable much quicker when the necessary programming is completed to permit electronic computation of data from punched tape.

Exploratory work on isolating potato protein fractions has demonstrated that considerable effort will likely be required on modification of conventional methods.

Work is also in progress on the subject of sugar-amino acid compounds formation in potato chip frying but this has not progressed to the stage that findings can be reported.

2. After-cooking Discoloration. While after-cooking discoloration can be controlled by dipping sliced potatoes in a dilute solution of an acid such as citric or the salt sodium acid pyrophosphate, processors would like to be able to solve the problem through agronomical changes. A large number of samples of potatoes, representing various degrees of discoloration, were examined during the report period. Since the discoloration usually occurs more intensely at the stem end of the tuber than at the bud end, emphasis has been placed on differences in chemical composition of the two ends. After making determinations of a rather large number of constituents and groups suspected of being involved in after-cooking discoloration, three factors appear to be of importance: potassium content; iron content; concentration of acids.

The potassium content was less in every case in the stem than in the bud end. Statistical analysis of all potato samples examined with respect potassium content and extent of after-cooking discoloration showed an inverse relationship significant at the 1% level.

Increased blackening was correlated with increasing iron content. This was evident for both iron which is "free", that is not precipitated by heat coagulation of the protein in the juice, and for iron that is associated with the protein. A relatively high amount of the total iron is associated with the protein.

The bud end of the tuber has a higher acid content, which is consistent with the lesser blackening tendency there. Three to ten times as much malic, citric, orthophosphoric and oxalic acids are present in the bud as in the stem end.

3. Organic Acids. A study of the changes in the amounts of non-volatile organic acids, occurring during 38° F. storage, was

completed in 1961. Knowledge of the extent of these changes, most rapid in the first two months of storage, is expected to be helpful in the development of relationships between potato composition and processing quality.

B. Dehydrated Potato Products

1. "Instantized" Pieces. It is believed that a great potential exists for dehydrated potato pieces that will rehydrate more rapidly than the conventional product. Methods have been developed for partially drying the pieces, rendering them porous by pressure build-up in a cereal gun followed by sudden release to atmospheric pressure, and finally drying the porous structure to low moisture content. Initial drying is carried out at somewhat above 120° F. A product of good uniformity in rehydration is obtained by "puffing" the pieces (3/8 inch cubes) at 40% moisture and in the pressure range of 55-65 p.s.i.g. "Instantized" dehydrated pieces will reconstitute in less than 5 minutes in boiling water as compared with 20-30 minutes for present commercial pieces. Cost estimates are now being prepared for projecting to large-scale operation.

2. Flakes and "Flakelets". Work on methods of producing potato flakes was completed in July 1961, with the satisfaction that it had resulted in present annual capacity to produce sixty million pounds of product, which is equivalent to .7 million bushels of potatoes yearly. Procedures were developed for producing high quality flakes by precooking potato slices, cooling, adding mono-glyceride emulsifier to provide "abuse tolerance", completing the cooking, and finally drum drying to give the end product. Through increased "abuse tolerance", it is possible to reduce the flake size and thereby increase the package density to 25-27 pounds per cubic foot while still retaining good texture on reconstitution. "Flakelets", having 45-50 pounds per cubic foot density, are produced by mixing the drum dried sheet, broken to about 1/4-inch size, with fresh mash of controlled moisture and then manipulating to achieve compaction and lamination. Flakelets are of interest to the QMC because of their high density, and of interest to industry because of the favorable estimate of cost to produce and the feasibility of using nitrogen packaging.

C. New and Improved Processing Technology

1. Potato Flakes and Flakelets Storage. Since the FDA has set a limit of 20 ppm of BHA plus BHT antioxidants in flakes, lower than the optimum for best storage stability, it has become advisable to search for other effective stabilizing agents. A flakelets storage test is now in progress in which mixed tocopherols and nitrogen pack are being compared with BHA plus BHT for effectiveness in stabilizing flavor of the product.

2. Technological Research in Processing. The project on technological research related to the potato processing industries was terminated in September 1961. This research resulted in important contributions including: development of streamlined methods for determining the fat content of chips and French fries and the SO₂ content of sulfited potatoes and flakes; determination of the factors governing the absorption of SO₂ by peeled, raw potatoes; utilization of the byproducts from chip and starch processing. It is anticipated that this area of work will be given further attention, with the development of a new line of research directed toward solution of current problems in the processing industries.

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USDA AND COOPERATIVE RESEARCH

Chemical composition as related to processing characteristics

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PROCESSING AND PRODUCTS
Western Utilization Research & Development Div., ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, is becoming more and more dependent upon the development of new and improved processed products to maintain markets and to avoid recurring economic disasters. Crop perishability, supply fluctuations, and the inelasticity of demand, result in wide swings in price with even slight surpluses. In producing areas having a substantial processing industry, depressive lows are moderated by advance contracting by processors prior to harvest. However, in many important potato growing areas processing has not yet developed, and vulnerability not only still exists, but is exaggerated by the growing competition of processed potato and other competing food products. A continuing improvement in processed potato products is clearly required if processing is to expand fast enough to offset the progressive decline in use of fresh potatoes.

To make possible required improvement in quality of processed potatoes, ways must be found to eliminate the stale, "earthy," rancid, "green," and "warmed-over" flavors that are sometimes encountered in potato products, including dehydrated mashed potatoes, dehydrated diced potatoes, frozen French fries, frozen patties, and potato chips. Equally important, methods must be devised for retaining the desirable natural flavor of the freshly cooked potato in the processed product. Recently developed research methods offer an opportunity to isolate and identify the chemical constituents responsible for the natural flavors and the off-flavors, to develop rapid and sensitive analytical methods for their measurement, and to determine the raw material factors controlling formation of the various desirable and undesirable constituents in the fresh potato. Further improvement in the texture of potato products is also needed. Fundamental histological and chemical investigations could be used to determine the causes of differences in the textural character of potatoes, as a basis for developing improved processing methods. Enzymes play a great part in controlling the entire compositional pattern of the potato, not only the constituents responsible for flavor, off-flavor, color, and texture, but also those responsible for disorders such as "black spot." "Black spot" causes severe losses both to those who market potatoes in fresh form, and to those who process potatoes, because trimming costs are sharply increased and product yields reduced. Greatly increased knowledge of enzymes is needed as a basis for solution of the black spot and other problems, to increase use of potatoes by reducing costs, and to improve quality of both fresh potatoes and processed potato products.

USDA PROGRAM

In the Western Utilization Research and Development Division, basic and applied research on potato products is conducted at the Division headquarters at Albany, California, and by grant funds under P.L. 480 in England. The chemistry of potato flavor and the compounds involved in deterioration of potato products are studied to provide a basis for new and improved potato processes and products. Histochemical studies are conducted to elucidate factors involved in the texture of potato products. Basic investigations on the enzyme systems involved in potato product discoloration and the role of sulfur dioxide in preventing non-enzymatic browning are in progress.

The Federal program of research in this area totals 7.6 professional man-years. Of this number, 3.6 are assigned to chemical composition related to flavor, color, and texture of potato products (including 0.5 professional man-year's support for a chemist whose salary is provided by the Instant Potato Granule Manufacturers Association), 0.5 to new and improved products based on dehydrated potatoes, and 3.5 to technological and engineering research on processing methods. In addition, the Division sponsors 6.6 professional man-years of research under P.L. 480 on basic studies.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Related program of all State Experiment Stations and industry and other organizations is reported by the Eastern Utilization Research and Development Division in Summary of Current Program and Preliminary Report of Progress.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition Related to Flavor, Color, and Texture of Potato Products

1. Flavor Components. Of great importance to flavor chemistry in recent years has been the application of gas-liquid chromatography techniques. High instrument sensitivity was achieved by use of dual columns with dual-flame ionization detectors so that it is now possible to separate and make tentative identification of important volatile components from the headspace atmosphere of a small flask containing only a gram or two of the food product under investigation. The procedure, developed at Albany, California, is sufficiently distinctive to warrant a special name. The instrumental record developed by the new procedure is called an "aromagram." Because extraction and concentration procedures are not required, the introduction of artifacts is minimized. Sample size required is very small; food samples can be withdrawn from processing lines at different stages or from packages during storage experience and analyzed for compositional changes

that may be correlated with subjective evaluations of products. The aromagram procedure is more sensitive by a factor of ten than any method previously used. However, while this is below the sensory threshold of many flavor components, it is not sensitive enough to detect some odorous compounds at levels detectable by the human nose. The aromagram method was developed, in part supported by the Instant Potato Granule Manufacturers Association. The method makes it possible to measure the concentration of certain compounds which are the result of oxidative deterioration (rancidification) of potato products, and of others which are the result of non-enzymatic browning (scorching). It is thus possible to measure objectively and quantitatively the degree of these two types of flavor change in any sample. Study of the various processing operations to determine their effects on product flavor is now possible on a rational basis and can be expected to lead to improved processes and products. Investigation of the chemistry of storage deterioration of products is likewise in progress, using the most advanced methods for measuring components.

2. Enzymatic Browning of Processed Potatoes. Fundamental studies on the enzymatic browning of potatoes are in progress at the Low Temperature Research Station in Cambridge, England, supported by a grant under P.L. 480. Browning does not occur until the cellular structure is damaged, as by peeling or bruising the potato and, perhaps, under some disease conditions. The nature, distribution, and mode of action of enzymes responsible for this type of brown discoloration of potatoes and potato products are investigated by several approaches. Relationships have been found between browning tendency and potato variety, location where grown (possibly cultural conditions), concentration of enzymes (tyrosinase and polyphenol oxidase), and concentration of the chemical substrates upon which the enzymes act (tyrosine and chlorogenic acid). A direct correlation has been found between concentration of one of these substrates (tyrosine) and enzymatic browning tendency, and the amount of tyrosine was found to be inversely correlated with the total solids content of potatoes. Factors that affect the tyrosine content in potatoes will now be investigated including the effect of variety, soil and fertilizer use, and climatic conditions. Related studies with one of the enzymes (polyphenolase) from other plant sources have been conducted to obtain a basic foundation for understanding the chemical and metabolic reactions involved in the phenolase-discoloration system.

3. The Role of Sulfur Dioxide in Dehydrated Vegetables. A fundamental investigation of the chemical fate of sulfur dioxide or sulfite in dehydrated vegetables is being conducted at the Covent Garden Laboratory in London, England supported by a grant under P.L. 480. The objective of this research is to determine the chemical mechanism through which sulfite exerts its protective action on dehydrated vegetables. Model chemical systems have been used in which the effects of sulfur dioxide and other components have been observed as they

affect simple browning reactants (e.g., glycine and glucose), and other more complicated chemical reactants (e.g., citral in place of glucose). By use of sulfur-35 as a radioactive tracer, the chemistry and migration of sulfite applied to potatoes during dehydration have been studied. By these means some of the complications of the mechanism through which sulfur dioxide prevents non-enzymatic browning are beginning to unfold. A common chemical structure in glucose and citral (the carbonyl group) is involved in a reaction with amino acids, such as glycine, as a primary step in forming the brown pigment. Citral is more reactive than glycine because of its unsaturated structure. Sulfite seems to block browning by prior reaction with the carbonyl, but unsaturation, as in citral, can be responsible for a rapid migration of the sulfite within the molecule, allowing a more rapid color formation by freeing the carbonyl. Effects of various reactants, calcium, iron, phosphate, and ascorbic acid (Vitamin C), on rate of browning are being elucidated in this study.

4. Potato Components Related to Cooking Texture. Contract research at the University of Idaho was completed, in which 69 lots of potatoes over a two-year period were analyzed. In addition, each lot was cooked by a standard procedure and evaluated by a rapid method developed to evaluate potato texture. The texture of cooked potatoes was positively correlated with total solids, alcohol-insoluble solids, starch concentration, total ash, and alkalinity of ash; it was not correlated with content of pectin, crude fiber, galactose, arabinose, calcium, magnesium, or phytate phosphorus. These findings support a conclusion that potato texture is closely related to starch content and that the composition of the cell wall and supporting tissue structures is not of major significance.

5. Potato Enzymes. A limited project was completed on enzymes concerned with sugar conversions in potatoes stored for processing. For the first time it was unequivocally demonstrated that potatoes contain an enzyme (uridine diphosphate glucose-fructose transglucosylase), which synthesizes sucrose (common sugar), and another enzyme (invertase), which removes sucrose by hydrolyzing it to the reducing sugars, fructose and glucose. Enzyme extracts from potatoes stored at low and high temperatures had equal sucrose-synthesizing activity. However, low temperature potatoes had three to four times the sucrose-splitting activity. Much more of the sugar-synthesizing enzyme was found in California White Rose variety potatoes, which tend to have a high sugar concentration, than in Russet Burbanks, which are low in sugar-forming tendency.

6. Antioxidant Activity of Polyphenolic Compounds. A fundamental investigation of the chemical mechanism of polyphenolic and other plant constituent antioxidants for use in enhancing the stability of food products, has been conducted at the Aberdeen, Scotland, Research

Establishment and Experimental Factory, sponsored by a grant under P.L. 480. The objective has been to develop new or improved stabilizers that will preserve the quality and improve consumer acceptance of processed foods. The investigators obtained information on the relation between the structure of polyphenols and their antioxidant activities. Such information is of a very basic nature and should be valuable in the extraction of natural plant constituents and their chemical alteration to provide practical antioxidants which combine the ideal chemical structural features with commercial availability. The closing of the Aberdeen laboratory by the British Ministry of Agriculture made necessary the premature termination of this research grant.

B. New and Improved Products Based on Dehydrated Potatoes

1. Product Developments. Investigations on new potato products are conducted, closely connected with technological and engineering research (see paragraph C,1). The use of existing potato products as ingredients of new formulated food products such as instant soups, crackers, and related food items is under consideration on a very limited scale.

C. Technological and Engineering Research on Processing Methods

1. Dehydrated Potato Granules. Alteration of starch in the tissue cells during processing is of primary significance to the textural quality of potato products. Release of gelled starch from ruptured tissue cells of mashed potatoes imparts a sticky or gummy texture. Several methods were found to mitigate this condition by manipulation of the properties of gelled starch in the cooked potatoes. Precook heat treatments and cooking at a controlled temperature below the boiling point resulted in greatly improved products by reducing rupture of tissue cells during processing. Edible food additives, including starch-complexing agents (such as calcium stearate and palmitate) and emulsifiers (such as glycerol monostearate and palmitate), reduce the stickiness of the free starch that is released by rupture of tissue cells. Analytical methods were developed whereby the amount of starch released could be measured in the presence of these additives, which interfere with the chemical method in common use (Blue Value Index). Another textural problem sometimes encountered in dehydrated potato granules is the tendency to incomplete rehydration, which results in a graininess in the reconstituted mashed potatoes. Natural gums, added at levels up to 0.5% of total solids, were found to control this defect. A wide range of conditions and additives were discovered that allow considerable opportunity for manipulation of the textural qualities of dehydrated mashed potato products. Pilot plant equipment was designed and constructed to study effects of various partial dehydration, mixing, and conditioning operations on the quality of dehydrated potato granules. Possible changes

in existing commercial practices were developed within limits of small-scale batch operations. Processing research has now been directed toward study of the unit operations that may adversely affect product flavor, by close coordination of experimental design with the fundamental investigations on flavor components (see paragraph A,1).

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Chemical Composition Related to Flavor, Color, and Texture of
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New and Improved Products Based on Dehydrated Potatoes

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Technological and Engineering Research on Processing Methods

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III. MARKETING RESEARCH

Market Quality

Market Quality Research Div , AMS

Problem. The problems arising from the number of potato varieties grown, areas of production, seasons of harvest and special storage and handling requirements for specific uses require a continuing program of research on handling, storage, transportation, physiology, wastage control and quality measurement. Current emphasis on processing has created special problems in prolonged storage at elevated temperatures and protection from low temperatures in transit. This has substantially increased the need for research on the control of moisture loss and the reduction of bacterial and fungal decay. Higher temperature storage also involves control of sprouting, with increased emphasis on chemical sprout inhibitors. There are also major problems in the area of quality measurement. Objective indices are needed to identify quality factors that are important for specific product usage. Also needed are non-destructive methods and instruments for detecting and rejecting potatoes with internal disorders during grading.

USDA PROGRAM

The Department has a continuing long-term program involving horticulturists, plant pathologists and plant physiologists engaged in applied and basic research. The work at East Grand Forks, Minnesota is conducted in cooperation with the Minnesota and North Dakota Agricultural Experiment Stations and the Red River Valley Potato Growers Association. The work at Presque Isle, Maine is in cooperation with the Maine Agricultural Experiment Station. Research on transportation of early potatoes for chips is conducted by the Fresno, California station. The studies at Beltsville involve specialized storage problems and basic research. Studies on market diseases are conducted at Chicago and New York City.

The Federal scientific effort devoted to research in this area totals 9.5 professional man-years. Of this number, 0.5 is devoted to objective measurement of quality; 1.3 to handling and packing; 2.3 to storage; 2.0 to quality maintenance during transportation; 1.0 to post-harvest physiology; 1.9 to post-harvest disease control, and 0.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported 7.8 professional man years as follows: objective measurement and evaluation of quality 1.1, handling and packaging 2.3, storage and transportation 4.3, and post-harvest disease control 0.1. Much of the work on handling and packaging is concerned with prepeeled potatoes.

Industry and Other Organizations: Potato processors devote approximately 2 man-years on biochemical changes in potatoes during storage as affecting suitability for processing. Chemical companies do a limited amount of research (approximately 2 man-years) on developing, formulating, and evaluating sprout inhibiting chemicals.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Determining Susceptibility to Bruising. An impact instrument was developed in cooperation with ARS to measure susceptibility to bruising. Growers in the Red River Valley complained in the fall of 1961 that most Red Pontiacs were too tender to handle without bruising or cracking whereas Norlands could be handled normally without trouble. The impact instrument showed Red Pontiacs were two to three times as susceptible to bruising as Norlands.

B. Quality maintenance in handling and packaging

1. Mechanical Injury Incident to Sizing Potatoes into Storage. In the Red River Valley, more bruising occurred in Norland potatoes sized into storage than those not sized but the bruising was largely confined to non-grade defects. About twice as many non-grade defects occurred in the sized potatoes as in unsized. As expected, potatoes in the two larger size groups had about two to three times as many non-grade defects as the small size group.

C. Quality maintenance in storage

1. Influence of Storage Temperature on Processing Quality of Potatoes. Twenty-four 1 ton capacity boxes were filled at East Grand Forks, Minnesota, with Irish Cobbler, Kennebec, Red Pontiac and Snowflake potatoes. Equal quantities of each variety were stored at 40°, 45°, and 50° F. The potatoes stored at 45° and 50° were treated with isopropyl N-(3 chlorophenyl) carbamate (CIPC) to inhibit sprouting. At monthly intervals for 10 months, 300-lb. lots were removed from storage for pilot-plant processing into potato flakes and slices. The data on quality of the products are not yet available.

2. Effect of Methods and Rates of Ventilation on Quality of Maine Potatoes. Maine potatoes stored with no forced air circulation for 154 days at 38° F., and 85 percent relative humidity lost approximately 6 1/2 percent in weight. Maintaining the same temperature and humidity at an air flow of 8 fpm increased weight loss to about 8 1/2 percent. By increasing the humidity to 95 percent the weight loss at 8 fpm was about 7 percent.

Instrumentation is being developed, in cooperation with the University of Maine, to measure low airflow velocities which occur within a bin of potatoes. Preliminary tests with the instrument show that most of the air flows along the outer edges of the bin and little air is actually forced through the top center of the pile even at relatively high input rates.

3. Deep Bin vs. Pallet Box Storage. Although data on weight losses and temperatures indicated relatively slight differences between the two systems, more total bruising resulted in deep bin storage than in pallet box storage in Maine. Approximately 9.6 percent of the tubers from the deep bin were classified as being damaged (5-10 percent waste) whereas only about 5 percent of the tubers in the pallet box were damaged. Serious damage (over 10 percent waste) was evident in 2 percent of the tubers from the bin whereas about 1 percent of the potatoes in the pallet boxes showed this condition.

Storage of potatoes in pallet boxes reduced the amount of pressure bruising and internal black spot as compared with potatoes stored in deep bins. In samples from deep bins approximately 14.5 percent of the potatoes had pressure bruised areas whereas in pallet boxes 7.7 percent of the potatoes showed this condition. After a holding period of 10 days, 1.1 percent of the potatoes from deep bin storage had developed internal black spot. None of the potatoes from pallet boxes had developed internal black spot.

4. Internal Sprouting. Tests were initiated at Beltsville in April 1961 to determine the causes of the serious losses associated with internal sprouting of potatoes during the 1960-61 season. Maine-grown Katahdin potatoes previously stored at 40° F. were treated with varying concentrations of isopropyl N-(3 chlorophenyl) carbamate (CIPC) in aerosol form. The amount of internal sprouting decreased as the concentration of CIPC was increased and the untreated check lots held at the same temperatures as treated samples had more internal sprouting than treated lots. Storage temperature was the most important factor in the development of internal sprouting. The percentage of tubers with internal sprouting after 5 months' storage at different temperatures were 50° - 1.5%, 60° - 14.4%, 70° - 9.8%.

Three varieties tested during the 1961-62 season showed a widely different response. Irish Cobbler samples had considerably more internal sprouting and averaged 31% in the untreated lots stored at 60° F. as compared to 13% for Kennebec and 7.5 % for Katahdin. Further tests with storage temperatures using the Katahdin variety showed the following percentages of internal sprouting: 50° - none, 55° - 0.3%, 60° - 13.6%, 65° - 19.6%, and 70° - 10.0 %.

In tests the first year potatoes treated with CIPC after sprouting had started, had slightly higher percentages of internal sprouting but differences were not significant the second year. Samples receiving two aerosol applications of CIPC about 2 weeks apart had somewhat less internal sprouting than those receiving only one application. Potatoes dipped in 0.5% suspension of CIPC did not develop internal or external sprouts during 5 or 6 months of storage.

D. Quality maintenance during transportation

1. Transit Temperatures of California Potatoes for Chipping. Early-season unwashed Kennebec potatoes shipped by rail from California to midwestern chip plants are usually shipped with vents open and no ice, unless potato temperatures at loading are extremely high. A shipment in which initial temperatures were 75° F. encountered average outside air temperatures of 90° maximum and of 63° minimum enroute. Average potato temperatures in transit were 68° when the vents were partly open (vents on irons) and 67° when the vents were fully open. The color of chips made with potatoes from both cars at arrival was good. Decay was negligible.

A shipment of washed potatoes that had a temperature of 95° at loading was iced with 1 ton of ice in each bunker and shipped with vents open. This shipment encountered average maximum and minimum temperatures of 93° and 64°, respectively. Although the average transit temperature (71°) of the potatoes was satisfactory, decay was excessive (65 to 68%), probably due to the high initial temperature and high moisture conditions resulting from washing.

Chip color, in relation to transit temperatures, was studied in the laboratory. Kennebecs held at 70° F. for simulated transit periods yielded chips with optimum color. Holding at 75° did not improve color and increased the amount of surface mold. Chips made from tubers held at 65° showed significant darkening and those from tubers held at 60° were so dark that they were on the borderline of acceptability.

2. Effect of Low Temperatures on Seed Potatoes. The seed value of four varieties of potatoes, exposed to freezing or near freezing temperatures, was tested in plantings in Maine, New York, and Delaware. Red Pontiac seed potatoes from East Grand Forks, Minnesota, and Katahdin, Irish Cobbler and Pungo seed potatoes from Aroostook County, Maine, were stored and treated at Beltsville, Maryland. All potatoes were stored at 40° F. before treatment and were held at 50° for 2 weeks after treatment before planting. Treatments were: (1) 40° F. continuously (standard), (2) 30° one day, (3) 30° ten days, (4) 25° F. one day (supercooled without freezing), and (5) 25° F. one day (with freezing symptoms produced by jarring).

Unless freezing (with visible symptoms) occurred in the seed tubers, freezing or near-freezing temperatures for up to 10 days did not adversely affect emergence, growth, or yields. This work has been completed.

E. Post-harvest physiology (Beltsville)

1. Phenolic Constituents and Their Relation to After-Cooking

Discoloration. The phenolase enzyme system was found to be present in potato cells in a soluble and also in a bound form. No specific localization within the cell could be established. Wounded tissues rapidly accumulated polyphenols consisting primarily of chlorogenic acid. Phenolase activity was also found to be greater in tissues that had been wounded. The tissues with accumulated polyphenols were somewhat darker in color after cooking than corresponding tissues with lower concentrations of polyphenols. This work has been completed.

2. Phenolase Enzyme Activity. The phenolase enzyme which causes the discoloration of freshly cut or injured potatoes was found widely distributed in various extracts of potatoes. When potato tissue was macerated a considerable portion of the enzyme was soluble in the water extract but some remained bound to the mitochondria and other small particles within the cell. Phenylthiourea in very low concentrations completely inhibited phenolase activity but had no effect on respiration of potato slices. No evidence could be found to indicate that phenolase acted as an important terminal oxidase in respiration or is involved in suberin formation. (Pioneering Laboratory)

3. Suberin Formation. A fluorescent microscope was used to study suberin formation in potato tissues. Light had no measurable effect on suberin formation. Oxygen was required but 2 percent was almost as effective as the normal atmospheric 20 or 21 percent. Numerous chemicals were added to the tissue slices to test their effect on suberin formation. Only (1) shikimic acid (2) eugenol or ferulic acid with hydrogen peroxide significantly increased suberin formation. (Pioneering Laboratory)

F. Post-harvest disease control

1. Pre-Storage Washing. Lenticel infection studies were initiated in Maine to determine whether maturity, interval between washing and harvest or storage temperatures prior to washing influenced the amount of lenticel infection in Katahdin potatoes. Maturity did not appear to affect the amount of lenticel infection. However, storage at 50° F. and approximately 85 percent relative humidity for 2 weeks or longer prior to washing reduced infection. All lots of washed potatoes showed more lenticel infection than unwashed potatoes.

Histological studies showed more suberin development beneath the lenticels of tubers stored at 50° F. than of tubers stored at 38° F. Suberin began to develop after approximately one week at 50° F. while tubers stored at 38° showed only slight evidence of suberin after 3 weeks storage.

2. Decay of Cut-Seed Pieces as Influenced by Previous Storage Temperature. Slices from Irish Cobbler, Sebago, Katahdin and Kennebec tubers stored at Beltsville for 4 months at 32° or 34° F. developed approximately the same amount of suberin and periderm at 70° as slices from tubers of the same varieties stored at 40°. However, slices from Pungo tubers stored 4 months at 32° developed slightly less suberin at 70° than slices from tubers stored 34° or 40°. They developed no periderm. Slices from tubers of each variety stored at 32° F., especially after only 2 days healing before inoculation with Erwinia carotovora, developed more decay than slices from tubers stored at 34° or 40°. More decay developed on Pungo slices than on slices of other varieties. These studies emphasize the need for avoidance of prolonged storage of seed potatoes at very low temperatures.

Sprouts emerged much more rapidly from seed pieces from tubers stored at 40° F. than from seed pieces from tubers stored at lower temperatures. Emergence was slowest from seed pieces from tubers stored at 32°. Almost a perfect stand existed 6 weeks after planting regardless of variety or storage temperature. The work on precut seed has been completed.

3. Relation of Oxygen and Carbon Dioxide to Decay. Studies at Beltsville of the effect of O₂ and CO₂ concentrations on bacterial decay of potatoes were continued. Oxygen concentrations below 6% increased the penetration of bacterial soft rot isolates into the slices. Indications were also obtained that decay of whole tubers and slices was increased when CO₂ was allowed to build up within the chambers. Sections from slices held in 6% or higher oxygen concentrations had strong fluorescence indicative of suberin formation when examined under an ultraviolet microscope. Those from 1% O₂ had only slight fluorescence. Periderm formed with O₂ concentrations as low as 8% but not below that.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Storage

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Transportation

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Post-Harvest Physiology

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Disease Control

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TRANSPORTATION AND MARKETING FACILITIES
Transportation and Facilities Research Div., AMS

Problem. Returns to producers and prices paid by consumers for potatoes are adversely affected by the use of inefficient marketing facilities, equipment, and methods. Better work methods, techniques, devices, operating procedures, equipment, and facility designs are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing, and packing.

Many of our conventional consumer packages and shipping containers are relatively expensive; require a substantial amount of labor to assemble, fill, and close; are comparatively heavy, hence costly to transport and difficult to handle; are unsuitable for storage; do not adequately protect their contents from damage; fail to make an attractive retail display to stimulate impulse buying; and lose potential sales because of poor visibility provided for contents.

Much of the transportation equipment now in use fails to give adequate protection to the more perishable commodities. Methods of loading often leave the container and product subject to mechanical damage in transit, result in poor utilization of available transportation equipment and hamper effective refrigeration. The substantial savings in labor costs incident to mechanized handling accomplished in other areas are not being realized in agricultural transportation. In the field of air transport, provisions for efficient and economical handling to and from airports and protection against heat and cold are inadequate. In the area of water transportation, the arrival condition of fruits and vegetables due to inadequate refrigeration, container, and stowing problems has seriously affected the market for United States products abroad.

USDA PROGRAM

Research on marketing facilities, equipment and methods is a continuing long-range program involving engineering research covering the development of improved work methods, techniques, devices, operation procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes. The research is carried on at the Red River Valley Potato Research Center, East Grand Forks, Minn.; the Maine Potato Research Center, Presque Isle, Me.; a field office at Gainesville, Fla., and the Washington office; in both laboratory and commercially-owned facilities; in North Dakota, Minnesota, Maine, Idaho, and Florida; in cooperation with the North Dakota, Minnesota, Maine, Idaho, and Florida Agricultural Experiment Stations, the Red River Valley Potato Growers'

Association, the Market Quality Research Division, the Marketing Economics Division of ERS, the Harvesting and Farm Processing Branch, Agricultural Engineering Research Division of ARS, and the Forest Products Laboratory of the Forest Service. This work utilized 5.4 Federal professional man-years in F.Y. 1962.

Work on consumer packages for early crop red potatoes was conducted with the cooperation of grower-shippers in Alabama and Florida and with receivers in various terminal markets; about .5 Federal professional man-year was devoted to this work in F.Y. 1962.

Research on improved loading methods for truck shipments is in cooperation with Florida and New Jersey grower-shippers, suppliers, and various terminal market receivers; about .3 Federal professional man-year was utilized in F.Y. 1962.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

The related research of the State Experiment Stations was not reported by commodities and is included in other reports. Virtually all of the USDA work is done with industry cooperation or participation and involves trade associations, equipment and supply manufacturers, and others mentioned above as cooperators.

Most of these industry members are interested in a wide variety of commodities. Professional man-years involved in their research efforts are not available for specific commodities. For summary statements for research on all commodities, see pages 46-47, 89, and 102-103 in the Transportation and Facilities report.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Handling and Packing Potatoes

1. Maine. Research under this project is directed toward reducing operating costs of potato storages and packinghouses by increasing the productivity of labor employed and reducing losses from bruises and mechanical injuries in handling, storing, cleaning, grading, sizing and packing potatoes. It involves the development of more efficient work methods, operating procedures, equipment, and facilities for handling, storing, and preparing for market Maine potatoes.

Summaries were compiled and a manuscript, covering methods and equipment presently used in Maine for handling potatoes from storage to packing line, was partly written. Systems for loading 50,000 and 100,000 pounds of potatoes per nine-hour day are being included in this publication.

Time and bruise studies were completed of the loading and unloading of a railroad car conveyORIZED for bulk shipment of potatoes to processors and repackers. A report on the findings from these studies also is in preparation. This report will include methods and equipment for making the most efficient use of this car, labor requirements, and labor savings resulting from the use of the bulk method in lieu of 50- and 100-pound bags. Savings of more than 40 percent of the labor costs involved in preparing a carload for shipment are possible. A 72,000-pound bulk carload can be loaded in less time and with fewer man-hours than normally are used for handling, preparing, and loading a standard 50,000-pound carload with bagged potatoes.

Studies were made of twenty-three commercial potato packing lines to determine the effect of various operating conditions of equipment and facilities on grading efficiency and accuracy. Only preliminary tabulations have been made of equipment speeds and produce flow rates.

Trials were made with a float-roll sorting table under controlled conditions of flow, translation and rotation speeds, and percentage of defective potatoes. Although further tests must be made before conclusions can be reached, these first studies indicate that rotation rates near 1.5 revolutions per foot of translation are the most efficient. In most cases the rotation rate affected the results more than the flow rate or the translation speed. This was especially true when the sample contained a low percentage (10 percent) of defective potatoes.

2. Florida. This program has as its objective the development of more efficient work methods, operating procedures, and equipment for the handling and preparation for market of potatoes in spring crop areas so as to reduce operating costs and losses from decay, bruises, mechanical injuries, and physiological breakdown.

Research on spring crop potatoes was confined to the study of two methods of handling at the packinghouse: (1) Bulk handling with a dump truck and fluming to the packing line, and (2) handling in pallet boxes.

Bulk Handling.--For the 1960-61 season a special holding bin was designed and built to allow potatoes dumped from the truck to be floated by water into the packinghouse flume which moved the potatoes to the packing line. Water was supplied from two sources: (1) A fire hose attached to one pump and (2) an auxiliary engine-driven pump, drawing water from the flume. The pumps were used in conjunction for floating potatoes out of the special bin. This method simulated conditions of flushing potatoes into a flume from a floor.

Checks showed that injury was greater with the conventional method than with the bulk method. A portion of this greater damage was attributed to the fact that conventionally handled potatoes were temporarily held in hopper-bottom bins. Results indicate that: (1) Approximately 600 gallons of water per minute are needed for floating potatoes out of the bin into the flume; (2) the bin bottom should have a slope of about 2 inches per 20 feet; (3) sand bags should be properly placed on the floor to help channel water to the points where it is needed; and (4) a high volume, light weight, flexible hose should be used in the operation.

The special flat-bottom bin constructed in 1960 for the experimental operation was modified for the 1961-62 season. The slope of the bin floor toward the main flume was reduced from 6 inches to 3 inches in 20 feet. A flume at the center, running the length of the bin, was built into the floor. A pipe was installed at the back (high) end of this flume so that water could be admitted there. In addition, a flexible hose for applying water at any desired point in the bin when fluming potatoes out was provided. Maximum water flow available was about 312 g.p.m. With this experimental setup, it was possible to flume out about 78 cwt. (one load) in 11.5 minutes, or at a rate of about 400 cwt. of potatoes per hour using only the flexible hose for applying water. Application of water from the back end of the flume was not found satisfactory.

Prior to the 1962 season the dump truck used in the tests was modified by having the floor covered with smooth sheet metal, an end-gate installed so that the driver could easily open and close it, and a special stop board attached underneath the truck which also could be operated conveniently by the driver to prevent potatoes rolling back where they would be injured or crushed by the rear wheels of the truck during dumping.

The cycle time required to dump a truck load of potatoes into the flat-bottom bin was 2.19 minutes. This was 19.8 percent faster than the cycle time during the previous season, and the number of workers required was reduced from two to one. The improved efficiency was mainly obtained through better equipment and work methods. The bulk dumping method shows potential for the fastest receiving, combined with least labor input, of any methods presently under consideration. With the hopper body and bin-piler system, unloading requires 9 to 15 minutes per truck load using a two-man crew.

Test runs were made during early, mid- and late season periods. Injury analysis showed similar results to the previous year. Potato injury was slightly less with the bulk dumping system than with the conventional hopper-body system.

In loading the dump truck directly from a mechanical harvester, the digging operation was not slowed. Allowing 16.5 minutes for loading the dump truck with 7,800 pounds of potatoes, 2.2 minutes at the packinghouse for dumping, 50 minutes for travel and 10 percent for miscellaneous delays, each truck could be expected to supply the packinghouse line at a rate of about 60 cwt. per hour.

Pallet Boxes.--This method involved the use of pallet boxes, a flat-bed motortruck, a forklift equipped tractor, and a pallet box dumper. The pallet boxes were taken six at a time to the field on the flat-bed truck, filled with about 1,500 pounds of potatoes each, and brought back to the packinghouse where the forklift tractor moved the boxes into temporary storage. During packing operations the filled boxes were moved by the tractor forklift from temporary storage to the dumper. Here the box was dumped emptying the potatoes into a flume which moved them to the packing line. Tests indicated that injury was about the same as with the conventional method which uses the hopper body truck and certain auxiliary equipment.

Preliminary time study data indicated that one forklift tractor having power steering, reversed operator position, and shuttle-type transmission, could feed a packing line at a rate of about 300 cwt. per hour. This rate is based on the handling of two boxes of 1,500-pound capacity each per trip. It involves one forklift tractor performing a complete cycle of moving filled boxes from trucks to a temporary storage area; moving filled boxes from that area to the dumper; moving empty boxes from the dumper to a temporary storage area; reloading trucks with empty boxes from that area; and a round-trip travel distance of 100- to 125-feet for each part of the cycle. Two workers would be used, one operating the tractor and the other operating the dumper. In a conventional operation of moving a similar volume from bins to the packing line, three workers are needed--one operating the hopper body, one attending the bin conveyor, and one regulating the gravity flow of potatoes from the bin into the flume.

Estimates indicate that a structure, having a roof and a concrete floor, for temporarily holding potatoes in pallet boxes would cost about \$2.30 per square foot less than the sloping-bottom bin type structure. With 1,500-pound capacity pallet boxes stacked 4-high, about 45 percent more potatoes could be accommodated in a given area than in bins.

During 1961-62 season the pallet box dumper was set up so that boxes followed a right angle flow pattern rather than the side-to-side pattern followed previously in moving boxes into and out of the dumper.

From preliminary evaluation of results, the conclusions from the previous season remain essentially unchanged. One suitable tractor forklift could supply a packing line at a rate of about 300 cwt. per hour. Moving directly between truck and dumper, with other conditions the same, one tractor forklift could supply about 390 cwt. per hour.

The indicated pallet box dumper capability (735 cwt. per hour under proper conditions) established during the 1961 season was unchanged by results of the 1962 season's work, except for greater time required for moving boxes into and out of the dumper with a right angle rather than side-to-side pattern. Although this has not been fully analyzed, effect on the dumper cycle should be small.

Six pallet boxes were handled per load on a flat-bed truck and filled directly from a mechanical harvester as was done previously in the experimental operation. Based upon observations and data, truck loading time in the field would be about 29 minutes for 90 cwt., and at the packinghouse the time for unloading filled boxes and reloading with empty boxes would be about 18 minutes.

Injury analysis showed similar results to the previous year. Potato injury was about the same with the pallet box system of handling as with the hopper-body system.

3. Red River Valley Potato Research Center, Minnesota. Work is directed toward developing more efficient work methods, techniques, devices, and equipment for handling and preparing for market mid-western fall-crop potatoes.

Handling.--Field studies were conducted and an analysis made of labor, equipment, materials, freight, space, and truck tieup time in loading, transporting, and processor handling of bulk potatoes in semitrailer trucks. A bulk bin was designed and methods synthesized to allow for temporary storage of bulk potatoes at the packer after sorting. A method was synthesized for unloading and temporarily storing in pallet boxes at the processor. A manuscript entitled "Bulk Handling and Shipping Process Potatoes in Semitrailer Trucks" which summarizes results of this work was completed. Time studies and analysis of data were continued on labor and equipment inputs for moving potatoes from storage to the packing line. These data will serve as the basis for the preparation of a manuscript entitled "Moving Potatoes from Storage to the Packing Line."

Cleaning and Sizing Before Storage.--This program is directed toward measuring the effects of cleaning and sizing fall-crop potatoes before storage on costs and efficiencies when compared with conventional practices; determining the best methods and equipment for performing these operations so as to reduce labor and facility requirements and mechanical damage in handling, storing, and preparing potatoes for market; and improving the storage environment for potatoes.

Tests were initiated during the 1960-61 season on this research. Red Pontiac potatoes were cleaned over a draper chain elevating conveyor and sized by an expanding pitch spool sizer. These potatoes were placed in six 400 cwt. capacity bulk bins separated as follows: (1) $1\frac{1}{2}$ to 2 inches--B size; (2) 2 to 3 inches--small A size; (3) $2\frac{1}{2}$ to $3\frac{1}{2}$ inches--large A size; (4) $3\frac{1}{2}$ inches and up; (5) field run cleaned but not sized; and (6) field run neither cleaned nor sized. During the storage period the effect of normal forced-air circulation and ventilation on bin temperature were observed by means of thermocouples installed during filling. It was found that environmental conditions of the cleaned and sized potatoes were slightly better than the uncleaned field run potatoes. Observation of the sizes indicates that a more satisfactory separation by size is needed.

During the 1961-62 season the high capacity (12 cwt./min.) expanding pitch spool, potato sizer developed for the 1960 crop altered and used to separate Norland potatoes into the four sizes: (1) Under 2 inches; (2) 2 inches to $2\frac{3}{4}$ inches; (3) $2\frac{3}{4}$ inches to $3\frac{1}{2}$ inches; and (4) $3\frac{1}{2}$ inches and over. The A-size (2 inches to $3\frac{1}{2}$ inches) was separated into two subsizes (2 inches to $2\frac{3}{4}$ inches and $2\frac{3}{4}$ inches to $3\frac{1}{2}$ inches) to meet table stock preferences in different localities. Overlapping sizes (2 inches to 3 inches and $2\frac{1}{2}$ inches to $3\frac{1}{2}$ inches) used in the 1960-61 season were dropped because they were not economically practical for table stock marketing.

A tilt-belt feeder was used to reduce pile-up in the center of the sizer by spreading the potatoes the width of the sizer. In the 1960-61 tests, the potatoes piled up in the center of the sizer and this was one of the reasons that poor sizing occurred.

For 1961-62 the sized potatoes did not show any advantage with respect to within-bin air circulation when compared to field-run potatoes.

B. Storage of Potatoes

1. Table Stock and Seed. Work under this program is directed toward providing optimum storage conditions for fall-crop potatoes; developing improved layouts and designs for potato storage and packinghouses which will permit the use of the most efficient handling and packing methods and keeping injury and mechanical injury to a minimum; while minimizing construction and maintenance costs.

The manuscript, "Shell Ventilated Systems for Potato Storages in the Fall-Crop Area," was completely rewritten. A first rough draft of a manuscript, "Fall-Crop Potato Storages," which includes recommendations regarding construction techniques, layout and design, air circulation and ventilation system, insulation, and building materials was prepared. A number of general plans are also included which were developed around the most efficient handling system and methods.

Line sketches have been prepared for ten general types of potato storages for fall-crop States. Ventilation and air circulation systems have been included in the designs of these storages. These drawings, when completely detailed, can be used to evaluate the handling facilities, construction costs, and operating costs of the most common types of storages in the fall-crop areas.

During the two-year report period, project personnel provided assistance on problems associated with storage construction and regulation, handling, and equipment to approximately 600 firms and individuals.

2. Processing. Four 10- x 18- x 10-feet deep, bulk storage bins at the Red River Valley Potato Research Center were converted into 40°, 45°, 50°, and 65° F. storage rooms. This remodeling included installing insulation, vapor barriers and sheathing. A 5-ton capacity heat pump, auxiliary blower, thermostats, and ducts were installed for regulating temperature in the individual rooms. Ceiling tracks, trolleys, and hoists were provided for moving pallet boxes between rooms and for weighing the boxes with a dial scale.

A closed circuit cooling system was installed in the 40° and 45° F. rooms so that all heat exchange between the refrigerated closed air circuit and the control rooms was through carefully vapor-proofed corrugated sheet metal ceilings. However, provisions were also made for direct cooling by circulating cold air in the rooms.

Two 1-ton pallet box lots each of Red Pontiac, Irish Cobbler, Norland, and Snowflake potatoes were stored in each of the 40°, 45°, and 50° F. holding rooms. In October, and bi-weekly thereafter, each one of the 24 1-ton boxes of potatoes were weighed and their specific gravity determined. Starting in February 1962, a 300-pound sample of each variety was removed every 4 weeks from each of the 3 control rooms. Samples from the 40° and 45° F. rooms were held for 4 weeks in the 65° F. conditioning room before being taken to the University of North Dakota pilot plant for processing into potato flakes and dehydrated slices. Samples from the 50° F. room were processed without further conditioning. The rooms were regulated by ventilation and electric heat until late in February when the heat pump was started. Regulation by the heat pump was satisfactory until about May 1; after which the temperatures could not be kept low enough. Sample lots were processed up to and including the first week in August. The UND made a preliminary comparative judgment of the quality of flakes from the lots for each storage period.

An analysis of the shrinkage data will be completed after the 1962 harvest season. Also the processing data from the UND pilot plant should be available by then. Specific gravity determinations showed no consistent change in any of the rooms during a 7-month storage period. Preliminary judgment was that the two lots of potatoes which were taken from the 45° and 50° F. rooms during the fourth week in July and the first week in August processed as well as the earlier lots of potatoes even though the earlier lots seemed firmer.

C. Consumer Packaging Early Red Potatoes

This work concentrated on the development and evaluation of consumer packages for the highly perishable early red potatoes grown in the Southeast in order to meet the growing demand of retailers for fresh produce prepackaged before it reaches the store. Five types of consumer packages were evaluated in comparison with conventional 50-pound burlap bags and multiwall paper bags; 10-pound paper bags with mesh windows; 5- and 10-pound polyethylene film bags; and 5- and 10-pound polyethylene mesh bags. The cost and performance of the bags was determined in 8 packing plants and in 29 test shipments sent to northern markets. Less bruising was found in all the consumer bags than in the conventional 50-pound bags. Cost of materials and direct packing labor ranged from 20 to 70 cents higher per 100-pound equivalent but retailers who prefer selling packaged produce were willing to pay the difference and often more. The 10-pound paper bags turned in the best performance with low cost and superior protection of product, although they did not provide as much visibility of contents as the polyethylene bags. However, the polyethylene bags exposed the potatoes to greening unless care was used in shielding them from too much light. The film bags, because of their relatively low moisture-vapor permeability, encouraged the development of decay if the organisms were present but for the same reason they retarded dehydration.

D. Improved Loading Methods for Truck Shipments of Potatoes

This work, which has been underway for the past three shipping seasons, has resulted in the development of two new loading patterns; one for 50-pound multiwall paper bags and one for 100-pound burlap bags. Formerly, bags of both sizes were stacked in a compact mass in the interior of truck trailer vans in such a way that the incoming outside air in ventilated shipments could not penetrate the main body of the load for removal of excess heat and moisture from shipments of early and mid-season potatoes. The new loading patterns for both sizes of bags, which can be used at no increase in cost and at no sacrifice in load weight, contain continuous longitudinal channels for effective air circulation through the entire load during transit.

Almost a thousand copies of a loading diagram for the new pattern for 50-pound paper bags have been requested and distributed to shippers and truckers, many of whom are now making wide use of the new loading method. Research currently underway deals with measuring the comparative effectiveness of more and larger perforations in multiwall paper bags in the new loading pattern to facilitate better protection of the product in transit. An interim report on the initial results of this research is now being reviewed for publication.

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IV. ECONOMIC RESEARCH

ECONOMICS OF MARKETING

Marketing Economics Division, ERS

Problem. Most agricultural processing industries are experiencing rapid and drastic changes in their market organization and practices. These changes are affecting both farmers and consumers. Research is needed to keep abreast of such changes and to indicate their probable consequences. There have been substantial advances in recent years in increasing efficiency and reducing costs through adoption of new technology in producing, assembling, processing, and distributing farm products. However, for producers and marketing firms to remain competitive additional information is needed on margins, costs, economics of scale and efficiencies possible in the marketing of farm products.

Marketing research also is increasingly concerned with evaluating present and prospective programs pertaining to agriculture, such as the Food Stamp Program and Federal Grading Activities and to the changing structure of market industries as this may influence the bargaining power of farmers. Research also is being directed to the economics of transportation and storage activities of both private firms and government. Increasing attention is being given to the longer-term outlook for various products and markets as an aid in better assessing the prospects for increasing industrial employment under the Rural Development Program and in assessing prospective interregional shifts in the areas of production and marketing for specific products.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural economists, economists, and personnel with dual economic and technical training engaged in research to determine the reasons for the changes that are taking place in marketing so that ways can be found to increase the efficiency of the marketing system and make it more responsive to changing public needs. This research covers all economic aspects of marketing from the time products leave the farm until they are purchased by ultimate consumers. It includes work on market potentials for new products and new uses, merchandising and promotion, and market structure, practices and competition. In fiscal year 1962, 3.4 Federal professional man-years were utilized in this work.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Most of the Experiment Stations in the potato growing States devote research resources to investigating various of the phases or areas in the field of economics of marketing, but information is not available by commodities on the professional man-years involved. The same situation holds true for the research by industry in this field.

Industry and other organizations including food manufacturers, industrial firms, producer associations and State agencies conduct or sponsor important research on new products and new uses. Most food manufacturers regard market potentials research as a necessary adjunct to their research and development programs for new food products. Among those industrial firms which process and market agricultural products most key firms have or retain competent research and development organizations. Results of these market research efforts mostly are kept confidential. Several producer associations sponsor research on development of new food products and contribute to the early stages of commercial trial and evaluation of these products.

Many of the Experiment Stations devote considerable research resources to investigating the market structure and practices for the various fruits and vegetables in many producing areas. A description of current practices provides a basis for knowing where inefficiencies are and what obstacles exist to improvement of marketing practices. Another phase of this research deals with the effects which changing technology and practices have upon the availability of markets and returns to the grower. An example of these projects is the study of how large-scale retail buyers operate, what they will expect of farmers in terms of commodity specifications, and marketing services, and how farmers may be compensated for performance of services, previously the responsibility of other sectors of our production-marketing system. Another element of these studies is the determination of processing and packaging plant location in relation to economy of size of producing area.

Maine is studying the effect of changes in transportation methods and practices upon the market area for Northeastern potatoes as a part of the cooperative regional effort, NEM-20, "Effects of Changing Marketing Practices on Product Quality, Consumer Acceptance, and Returns in Marketing Potatoes." Idaho is studying the degree of competition between fresh and processed potatoes and the present and potential demand for processed potato products as a basis for developing guidance to the Idaho potato industry.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Market Potentials for Processed Potatoes in Selected Outlets. Potato processing has increased greatly in recent years and is thought to be instrumental in halting the long-term downward trend in potato consumption. Work to determine the degree of market penetration of processed potato products and other economic considerations has been completed and the results have been published. Final analyses of the retail sales of processed potatoes in Philadelphia, Milwaukee, New Orleans, and Oakland during 1960, and institutional use in Philadelphia show that considerable penetration has been made in both the institutional and household markets, and there appears to be no expectation that growth in these markets will slow down in the near future.

The results of additional research concerning the comparative cost of processed potatoes to consumers and other economic considerations show that if a reasonable value were put on the homemaker's time many processed potato products would have a lower cost than fresh or home-made. A taste panel also found that most brands of processed potato products were comparable in eating quality to fresh potatoes.

Relative Costs of Convenience Foods. This research was designed to determine whether the ever increasing number of convenience foods increase retail food prices. Comparisons were made of prices paid by consumers for convenience type foods and the same foods in fresh or less highly processed forms. A preliminary report of the findings was published. These analyses revealed that of the 158 convenience type foods in the study only 42 were less expensive than their home-prepared counterparts. The remaining 116 were more expensive. Yet, in the quantities purchased by this country's discriminating housewives, the effect of the less expensive convenience foods outweighed the effect of the more expensive convenience foods by \$1.07 per \$100 spent in grocery stores for food. That is, the cost of purchasing the \$14.03 worth of convenience foods in fresh or homemade form would have been \$15.10 -- or \$1.07 more than purchasing them in their convenience form.

Economic Impact of Freeze-Drying. New technology can have tremendous consequences and their impacts need to be evaluated with special reference to costs, market structure, labor demand and utilization, capital needs, and market demand. Freeze-drying is an emerging technology of possible major import which requires study to ascertain its place and impact in the marketing system. Since initiation of this newly formed industry, a test panel for existing commercial products was established with the cooperation of the Agricultural Research Service at Beltsville. Also, with the cooperation of plants either commercially processing or experimenting with commercial pilot operations, and from representatives of equipment companies, data has been gathered which will form a basis for a synthetic projection of

what costs may be anticipated with model plants constructed in the following sizes: 4 tons, 8 tons, 16 tons, and 32 tons of water removable ability for a 24-hour period. Work has been initiated to use such engineering synthetic cost data to estimate the impact of freeze-drying upon food processing industries and in the process to estimate the long-run potential of the freeze-dry industry.

The taste panel work covered approximately 30 freeze-dry products now on the market. Comparisons of current frozen and canned products of standard quality were used as a frame of reference for the testing of the prepared freeze-dried foods. Preliminary results suggest many of the products are satisfactory from a taste standpoint. However, a few appear to be unsatisfactory.

Preliminary estimates imply that the cost per pound of water removed will approximate 7 cents for a low volume capacity operated plant, and about $3\frac{1}{2}$ cents for a large capacity operated plant. A full report of the engineering synthetic costs should be ready for publication during the fiscal year.

Market Potentials -- Liaison Between ERS and Utilization Research, ARS
An agricultural economist is stationed at each Regional Utilization Research and Development Division to provide liaison between the regional laboratories, ARS, and the Economic Research Service in order that economic research may be teamed with physical science research in approaching problems relating to new products and new uses. Phases of work are as follows: (1) To delineate the economic problems involved in developing markets for new and extended uses of commodities on which the laboratories are working; (2) to develop and assist in carrying out research studies for providing information that would aid the laboratories in deciding what particular products or processes would be most likely to be economically feasible; and (3) to develop and assist in carrying out research studies for appraising new products and processes developed by the laboratories, including studies of market potentials, comparative costs, and studies of the probable impact of new developments on sales and farm income.

Market Structure, Practices and Competition. The wholesale fruit and vegetable business is a static industry in the midst of a dynamic economy. The total volume of fresh fruits and vegetables for off-farm civilian consumption increased 12 percent from 1935-39 to 1957-61, while the total volume of all food was increased nearly 60 percent. Direct buying from shipping points by chains and other retail organizations has increased sharply, and the total volume of business of wholesalers has declined. The number of major wholesalers is declining. These changes in structure create severe strains within the industry both at the wholesale and the shipping point level. Their impacts on farmers, in terms of the demands for their products (quality, uniformity, packaging, quantity, etc.) are marked. Wholesalers, packers,

shippers, and farmers will find it increasingly necessary to make adjustments to the different types of buyers with whom they must deal and their requirements.

Rapid development of potato processing in recent years has greatly affected the whole structure of potato marketing. Frozen french-fried potatoes are now the most important frozen vegetable product in volume. In the Northwest, the number of potato processing plants has increased from seven in the early 1950's to twenty-two in 1961 in response to a strong demand for processed potato products, improvements in product quality, and substantial innovation profits to processors. But the outlook for the industry is no longer so favorable. In the Northwest, plant capacity is excessive except for frozen french fries, and new plants are coming into operation in other major producing areas. As a result, competition for outlets is increasing rapidly among plants and among areas. Thus, the relative costs of producing and marketing various processed potato products will greatly affect the location of production and other adjustments in the potato industry.

Costs of processing field-run potatoes were found to vary between 87 cents per hundredweight for granule to \$1.24 per hundredweight for frozen french fries. This did not include the cost of raw product, packaging or selling and distribution. Packaging costs varied from $3\frac{1}{2}$ cents per pound for granules in institutional pack to 9 cents per pound for retail packaging flakes.

Particular attention has been given to studying competition in marketing Idaho potatoes in competition with Maine and North Dakota in Chicago, New York, Atlanta, Dallas, Denver and Los Angeles. The price of Idaho potatoes was consistently higher in all markets.

Use of Marketing Information. Appraisal of the use of marketing information by potato producers in southern California revealed that most producers considered information adequate for their needs. There was a relationship between the degree to which information is searched out and degree producers engage directly in decisions.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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IMPROVING MARKETING OPERATIONS THROUGH
RESEARCH WITH FARMER COOPERATIVES
Marketing Division, FCS

Problem. Farmers, in marketing their production, face a revolutionary change in terms of market organization and marketing practices. The ever increasing and important supermarkets require large quantities, good quality, and frequent delivery which the small farmer, working alone, or a cooperative, or local firm of limited size cannot supply. Cooperatives must find ways to consolidate volume, either through internal growth, merger, acquisition or federation to help them meet the needs of mass merchandising. Ways must also be found to reduce marketing costs by increasing efficiency through improved operations, better organizations, and more mechanization.

Farmer cooperatives are an important part of the distribution system and represent a major potential for meeting the farmers' marketing problems in the modern distribution system. They are organized and operated to increase farmers' net income. Through cooperatives farmers seek to increase their bargaining power; obtain needed services at cost; improve the quality of farm products; and obtain a larger share of the consumer's dollar. Cooperatives face many problems in achieving these objectives. Research is needed which will assist marketing cooperatives, as well as other marketing agencies, solve their problems by making available essential factual information and developing practical and useful operating plans and procedures.

USDA PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operations and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms.

The number of Federal professional man-years involved in the work for all commodities totals 24.8, of which .9 is devoted to potatoes.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

In 1961, the State Experiment Stations reported no work with potato marketing cooperatives.

The majority of the research work of marketing cooperatives is in the area of merchandising and promotion, although some cooperatives are studying feasibilities of having products graded and packed on the farm. Some farm supply cooperatives have formalized economic research departments, and part of their programs are concerned with the marketing of farm products. A few cooperatives now have employed management consultants to study and advise them on organizational and personnel problems.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Improving Operating Methods. To provide guidelines to growers on improved methods of marketing their potatoes, work is underway on the practices and preferences of buyers obtaining supplies from the Eastern Shore of Virginia. This work is being done jointly with the Virginia State Department of Agriculture.

ECONOMIC AND STATISTICAL ANALYSIS
Economic and Statistical Analysis Div., ERS

Problem. Adequate and accurate information is needed on supplies, production and consumption of farm products, and the effects these and other factors have on the prices of agricultural commodities. Such information is needed in planning operations for the producers, processors and distributors and also benefits the consumer in selecting his purchases. Similarly accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products are needed by Congress and the Administrators of farm programs to effectively evaluate current and future price support and production control programs.

Due to the instability of the prices he receives, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The farmer needs to be provided with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook intelligence and the development of longer range projections of the economic prospects for the principal agricultural commodities.

USDA PROGRAM

Supply, Demand and Price. Research on potatoes involves separate analyses for the total U. S. crop, the various seasonal crops, and special analyses for the major producing areas. These analyses measure the effect of price and other factors on acreage and production of potatoes; the effect of supplies and other factors on price and utilization of potatoes; the effect of price, income and other factors on consumption; and the effect of price and other factors on storage demand and level of storage. This work involves .5 professional man-years located in Washington, D. C.

Commodity Situation and Outlook Analysis. The outlook and situation program involves a continuing appraisal of the current and prospective economic situation of potatoes. Results of these appraisals, findings of special studies, and long-time series of basic data are published in quarterly issues of the Vegetable Situation, the National Food Situation, and the Demand and Price Situation. A comprehensive analysis of the potato situation is presented at the Annual Outlook Conference. Outlook presentations also are made at regional or State outlook meetings, meetings of farm organizations, and to various agricultural industry groups. Special studies are made from time to time to determine probable effect of proposed programs on supply, price and consumption of potatoes. Basic statistical series are compiled, improved and

maintained for use in statistical and economic analysis. This work involves .5 professional man-years in Washington, D. C.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

All State Experiment Stations are engaged in price research to fulfill the needs of farmers, handlers, and processors for information necessary for intelligent production and marketing decisions. The USDA provides much of the basic and background information but more geographic specifics and more detailed analysis is often requested of the experiment stations.

A few private colleges and organizations are engaged in price research and may give attention to agricultural products from time to time.

A substantial number of private organizations--including manufacturers of food and fiber products, private commodity analysis, banks and investment houses--are engaged in commodity outlook work similar to that carried on by USDA. This work, however, frequently relates to shorter time periods than those covered by the Department's outlook appraisals; is predominately for private use; and not available to the public.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Supply, Demand and Price. An overall study of the economics of the potato industry was conducted and results published as Agricultural Economic Report No. 6. Sharply declining per capita consumption of potatoes up until about 1950, rapidly increasing specialization and concentration of production, and significant changes in utilization and marketing practices were examined particularly as they related to the present status and problems of the industry. Growth in processing in recent years is credited with halting the long-time downtrend in per capita consumption of potatoes. Although acreage is now less than half that of 1920, production is moderately larger, as a result of sharply higher yield per acre. Marked shifts have occurred in the geographic pattern of production with the Western region expanding rapidly to gain 45 percent of the late crop market while the Central region's share dropped to about 25 percent. The Eastern States about maintained their position in the industry, at roughly a third of the U. S. total.

The demand for potatoes was found to be highly inelastic. During the last decade a 1-percent change in production resulted, on the average, in an opposite change of 4 to 5 percent in prices to growers. Because of this highly inelastic demand, even moderate variations in production cause sharp changes in price and income.

This study also analyzed the price-production interrelationships for important producing States. The analyses indicated that price and income stability in a given producing area is affected by changes in production in a competing area. The results showed that prices received by farmers for potatoes in Maine are influenced as much by changes in production in competing areas--for example, production in other Eastern States--as by changes in Maine production. Probably because of the type of potato produced in Idaho, changes in production outside the State had less impact on Idaho prices than the situation reported for Maine.

Another aspect of this study included an analysis of methods to cope with fluctuations in price and income to potato growers by making the demand for potatoes more responsive, or minimizing the variations in supplies available. This involved evaluating proposals to make demand more elastic by superimposing a Government "demand" through some price support, purchase, or income payment program on the existing free market demand. Ways of attaining effective supply management through marketing quotas or through a combination of acreage allotments and marketing quotas also were considered.

A first draft of a technical bulletin on supply, demand and price structure for potatoes has been completed. Some of the findings, particularly those dealing with demand, covered in this manuscript have been summarized in the previous reporting period. Findings during the current reporting period are confined to analyses of supply response for each of the seasonal potato crops. Separate analyses were run measuring the effect of previous year's price on acreage of potatoes planted and on total production. The results showed that price responsiveness varied among the seasonal crops. For example, during the postwar period, farmers tended to increase (or decrease) the acreage in spring crops by 2 to 3 percent following an increase (or decrease) of 10 percent in price. In the case of the early summer and late summer and fall crops, the response was only a little over 1 percent. The analyses indicated that response to price of total supply was also inelastic--a 2-percent change in production was indicated following a 10-percent change in price. Although the price response is low, significant year-to-year changes in acreage and production of potatoes occur mainly because of substantial year-to-year variations in potato prices.

A paper was prepared on storage demand for late summer and fall potatoes. It was found that sustained price increases or decreases affect out-of-storage movement of potatoes between January 1 and April 30.

Commodity Situation and Outlook Analysis. Potatoes have been in burdensome supply and prices relatively low all year long, mainly because of a very large crop last fall. Over 19 million hundredweight of U. S. No. 2 or better grade potatoes from the 1961 crop were diverted to starch and livestock feed, under the USDA diversion program, at a cost of \$10.1 million. The 1962 fall crop is down 6 percent from that of 1961, but still is well above normal trade requirements.

A comprehensive research report, An Economic Study of the Potato Industry, notes that during the last decade, year-to-year variation in prices to potato growers averaged almost 50 percent. This serious instability in prices, and consequently in producers' income, results from a combination of the inelasticity of demand for potatoes and from variations in production. Because of this inelastic demand a 5 percent change in production of potatoes results, on the average, in an opposite change of 20 to 25 percent in price to growers. The tendency of the industry to overproduce, and the consequent depressing effect on prices also is examined.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Supply, Demand and Price

- Hee, Olman. 1961. Storage demand for perishable potatoes. *Journal Farm Economics*, 43(5), pp. 1410-1411.
- Simmons, Will M. 1962. An economic study of the U. S. potato industry. U. S. Department of Agriculture, *Agricultural Economics Report 6*, 83 pp.

Commodity Situation and Outlook Analysis

- Simmons, W. M. April 1962. Potato price and income problems. *Vegetable Situation*.
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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION--
HOUSEHOLD AND INDUSTRIAL
Standards and Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for the consumer to express to producers either his pleasure or displeasure with available merchandise. In order to market agricultural products more efficiently, we need to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on preferences, levels of information or misinformation, and satisfactions or dislikes of both present and potential consumers. We also need to know consumer attitudes toward the old and new product forms of agricultural commodities and their competitors, and probable trends in the consumption of farm products. We need to know the relationship between agricultural and nonagricultural products and the relationship of one agricultural commodity to another in consumers' patterns of use. Producer and industry groups and marketing agencies consider this information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increase returns to growers.

USDA PROGRAM

The Special Surveys Branch of the Standards and Research Division conducts applied research on representative samples of industrial, institutional, or household consumers and potential consumers, in local, regional, or national marketing areas. Such research may be conducted to determine: attitudes, preferences, buying practices, and use habits with respect to various agricultural commodities and their specific attributes; the role of competitive products, and acceptance of new or improved products.

The Special Surveys Branch also conducts laboratory and field experiments in sensory discrimination of different qualities of a product. These studies ordinarily relate discrimination to preferences and attitudes as they influence purchases in order to assess the standards of quality, packaging, etc., which are needed to satisfy consumer demands.

The work of the Branch is carried out in cooperation with other Federal governmental agencies, divisions within the Department of Agriculture, State Experiment Stations, Departments of Agriculture, and land grant colleges, agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff, with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D. C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch.

The Federal scientific effort devoted to research in this area during the past year totaled 7.0 professional man-years, of which .1 was devoted to work on potatoes and potato products.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Agricultural Experiment Stations. The Stations do not report any of their work under this heading. However, they do have a considerable program in the area of consumer buying and use practices and motivation and decision making. This includes some research in preference and quality discrimination. There is a reference to parts of the Stations' program in other division reports.

Industry and Other Organizations conduct research in this area, but the research done by individual firms and organizations is almost without exception for their exclusive internal use. There are very few instances in which the findings are made public or made available for government reference. In addition to the research actually initiated and paid for directly by industry, a substantial amount is undertaken in their behalf as part of the service provided by their advertising agencies.

Producer Groups. A number of food producer groups conduct consumer preference work with their own staff and, in addition, contract for research with private marketing firms. To a large extent, this research is limited to food classes such as poultry, dairy products, citrus and deciduous fruits (rather than being directed to individual branded products). This research ranges from a small to national coverage. It includes taste testing for quality differentiation, new product acceptance, and attitudes toward existing products.

Food Processors. A sizeable number of food processors have extremely large programs of consumer research. They are engaged in work on new food forms and convenience foods such as cake mixes, canned and frozen fruits and vegetables, deciduous fruits, citrus fruits, soups, dairy products, and alcoholic beverages. Manufacturers of dehydrated foods, such as potatoes, are constantly engaged in consumer research on their own and on competitors' products.

Miscellaneous Groups: There is a smaller but constant amount of research undertaken by magazines and publishing houses for their principal advertisers. A number of the largest retail stores in our major cities study the consumers' reactions to their merchandise and service by conducting interview studies with customers and noncustomers. One of the

largest food retailing chains has an active program in quality research which involves taste testing as well as consumer preference.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Frozen French-Fried Potatoes -- Quality Discrimination. A report has been published on an experiment conducted under contract to determine whether or not household consumers could discriminate among four different packs of frozen french-fried potatoes containing variable amounts of slivers, small, and irregular pieces; and if they could discriminate, whether or not they had any preferences regarding uniformity of quality. This study was conducted at the request of the Fruit and Vegetable Division of the Agricultural Marketing Service to aid in the development of standards for grades. A cross-section sample of households in Pittsburg, Pa., tested the four packs, one per week, through four weeks. Results of the experiment indicate that homemakers tended to rate a pack higher and to prefer it more as it became more uniform in size and composition, and that it is probably somewhere between the 15- and 30-percent levels that the proportion of slivers, small pieces, and irregular pieces may become objectionable to consumers.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Discrimination

Linstrom, H. R. 1961. Frozen french-fried potatoes--effect of size of pieces on consumer preferences. Marketing Research Report No. 514.

V. NUTRITION AND CONSUMER-USE RESEARCH

Human Nutrition Research Division, ARS
Consumer and Food Economics Research Div., ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help carry out the Department's responsibility to advise on the quantity and variety of foods that will assure maximum benefit and satisfaction to consumers, continuous research is essential on the nutritional requirements of persons of all age groups, and on the nutrient and other inherent values of foods and how to conserve or enhance these values in household preparation and processing. Periodic examinations of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective nutrition education. Such information provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and use.

USDA PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care, and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition education programs.

The research is carried out by two Divisions of the Agricultural Research Service -- the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done in Washington, D. C. and at Beltsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 61.1 man-years. It is estimated that approximately 1.6 Federal professional man-years are utilized in studies related to white or Irish potatoes.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and micro-organisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research is described on a nutrient basis in the report for the Food and Nutrition Advisory Committee. The total Federal effort is 29.5 professional man-years.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Station research in 1961 included 22.4 professional man-years devoted to studies of the inherent properties of foods and of their household use; 17.6 to analyses of a variety of foods for vitamins, various lipid and protein components, and minerals; and 2.7 to studies of food consumption and dietary levels of households and of food management practices. Although the State work has not been reported on a commodity basis, some of the above research is applicable to this report.

Industry and other organizations such as universities and professional organizations are estimated to devote about 36 man-years to research on the preparation of materials for nutrition education, surveys of diets of individuals, and studies of functional properties and stability of food and of their specific nutrient contents. Limited work is done on the amount and structure of nutrients in foods and on compiling food composition data. Again, some of this work is applicable to this report.

REPORT OF PROGRESS OF USDA AND COOPERATIVE PROGRAMS

A. Nutritive Values of Foods

1. Tables of Food Composition. Data review has been completed for a revised edition of Agriculture Handbook No. 8, "Composition of Foods... Raw, Processed, Prepared." This edition will have nearly 2,500 food items as compared with 751 items of the preceding edition, and upwards of 45,000 separate compositional values. For many foods, data will be provided for different forms--raw, cooked, canned, frozen, milled, dried, instant, dietetic, etc. The new publication will have, in addition to other constituents, data for protein, fat, carbohydrate, five vitamins (vitamin A, niacin, riboflavin, thiamine, ascorbic acid), six minerals (calcium, phosphorus, iron, sodium, potassium, magnesium). Explanatory notes for foods and nutrients will be added for users of the tables. Information on cholesterol and fatty acids will also be included.

Data for potatoes will be included under five major subheadings; raw, cooked, canned, precooked dehydrated, and frozen, in the revision of Handbook 8. Data for potatoes cooked according to 10 different methods of preparation will be listed separately. Data for flake and granule "instant" potatoes will be shown for the dehydrated and for the ready-to-serve forms. A few soups and baby foods containing potatoes will also be included in the new edition of the tables.

2. Proximate Composition. Determination of the proximate composition of foods, i.e., moisture, fat, kjeldahl nitrogen and ash, were carried out in conjunction with studies for other nutrients in foods such as the vitamins, mineral elements, fatty acids and carbohydrates. Such an arrangement added to the information on composition of foods in the various commodity groups and also permitted the calculation of nutrients on a fat free-moisture free basis or on a nitrogen or protein basis where relationships among nutrients were concerned.

Proximate analyses on some 42 potato products have been made. These include homemade mashed potatoes and commercial preparations including dry mix for mashed potatoes; the mashed product prepared for serving, french fries, potato patties, potato puff, scalloped, hash brown and au gratin potatoes. The studies are being summarized.

B. Food Properties Related to Quality and Consumer-Use

1. Convenience Forms. Yield in servings per pound, preparation time, palatability and ingredient cost of frozen, dehydrated and canned potato products were compared with those of comparable products made from fresh potatoes as part of a cooperative study with the Economic Research Service. Total preparation time, and in most cases active preparation time, was longest for products made from fresh potatoes. Acceptability ratings for most frozen, dehydrated and canned products were good, in many cases comparable to products made from fresh potatoes. Some brand differences in eating quality were evident. Processed potato products cost more per serving than comparable products made from fresh potatoes if no monetary value was placed on the home-maker's time. A manuscript reporting results has been accepted for publication in the Journal of Home Economics. Results also have been used in marketing research reports.

2. Use of Agricultural Chemicals. The activity of cytochrome and polyphenol oxidases was significantly higher and phenolic content significantly lower in Cobbler potatoes grown in soil treated with PCNB (50 pounds pentachloronitrobenzene per acre) than in untreated soil. The activity of both enzymes decreased and phenolic content increased with storage. Uncooked potatoes grown in PCNB treated soil were significantly more discolored as to center tissue and redness than those grown in untreated soil. The cooked potatoes from PCNB treated soil had significantly more off-flavor than those from untreated soil

but the color was similar for both lots. These differences were observed shortly after harvest between potatoes grown in PCNB treated and untreated soil but were not significant after three months' storage at 40° F.

C. Food Economics and Diet Appraisal

1. Food Consumption and Dietary Levels. Information on the nutritive value of the food consumption of households based on the 1955 survey data has been summarized in Report No. 16 of the 1955 Household Food Consumption Survey series. Average family food supplies for a week in 1955 were sufficient to provide more than the National Research Council's recommended allowances for calories and eight nutrients for which values were calculated. However, many households (43 percent) had diets that did not fully meet the allowances in one or more nutrients. Other analyses of survey data show the relation of family size, the education of the homemaker, and of income to the food consumption of households. Because of interest in information on quantities of foods used by high consumers as well as average consumers estimates were made for some 60 food items of the ninth decile--the figure dividing the highest 10 percent of the consumers from the lowest 90 percent. For the potato, sweetpotato total, the amount consumer per person in "high consumption" households was nearly twice as much as in "average consumption" households.

Two surveys were conducted cooperatively with the Marketing Research Division, Economic Research Service in Detroit, Michigan and Fayette County, Pennsylvania to provide evidence on the extent to which food consumption is increased and diets improved as a result of the Food Stamp Program.

A report of the food consumption and dietary levels of a group of older, low-income households in Rochester, New York is in preparation.

Work is being undertaken on food consumption and nutritive content of diets of individuals. A systematic review and summarization of quantities of food consumed is being made through a cooperative agreement with the Minnesota Agricultural Experiment Station. A similar review of the nutritive content of the diets of individuals is being made by the Washington staff.

The nutrient content of the per capita food supply, calculated each year, using data on retail weight quantities of food as developed by the Economic Research Service, provides the only source information on year-to-year changes from 1909 to date.

2. Food Management Practices. Information on the kinds, amount, and nutritive value of foods used and discarded in households has been obtained in a series of small studies. Results will help to evaluate survey data on household food consumption.

A report on household practices in handling and storing of frozen food has been prepared, based on surveys in Baltimore, Maryland, and Indianapolis, Indiana. Households provided information on the length of time frozen food was held in home storage, and the temperature of the compartment in which frozen food was being held at the time of the interview.

3. Development of Food Budgets and Other Basic Data for Food and Nutrition Programs. An important aspect of nutrition research is the interpretation and application of research findings to practical problems of food selection in relation to health. An ongoing program of work includes assembling and interpreting available information on nutritional needs, food consumption, and nutritional value of foods for use by nutritionists, teachers, health workers, and other leaders concerned with nutrition education programs.

A technical report explaining the development of the food budgets, "Family Food Plans and Food Costs," has been completed and is in press. Another in the series of popular publications on food management has been prepared, "Food for the Young Couple." A publication, "Family Food Budgeting...for good meals and good nutrition," designed to help families of all sizes is also being prepared.

Regular pricing of family low-cost, moderate-cost, and liberal food plans is published in Family Economics Review on a quarterly basis for the U. S. average and on an annual basis for the regions and the low-cost food plan for the South. Each plan gives suggested quantities of food that will meet nutritional needs for each of 17 age and sex groups and for women during pregnancy and lactation so that household or population totals may be obtained.

Nutrition Committee News, a bimonthly periodical prepared for members of State nutrition committees and other workers in nutrition education provides a channel for disseminating pertinent information and for reporting nutrition education activities. A Nutrition Education Conference sponsored jointly by USDA through its Nutrition Programs Service and by the Interagency Committee on Nutrition Education was held in Washington, D. C., January 29-31, 1962.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Nutritive Value of Foods

Consumer and Food Economics Research Division. 1960. Nutritive value of foods. Home and Garden Bulletin 72, 30 pp.

Food Properties Related to Quality and Consumer-Use

Human Nutrition Research Division. 1960. Home care of purchased frozen foods. Home and Garden Bulletin 69, 6 pp., illustrated.

Human Nutrition Research Division. 1961. Storing perishable foods in the home. Home and Garden Bulletin 78, 12 pp., illustrated.

Demonstrations featuring donated foods in family meals. 1962. AMS-463, 30 pp., illustrated.

Food Consumption and Dietary Levels

Adelson, S. F. 1961. Practical procedures for dietary surveys. Proceedings 3rd International Congress of Dietetics. pp. 158-163.

LeBovit, C., Cofer, E., Murray, J., and Clark, F. 1961. Dietary evaluation of food used in households in the United States. Household Food Consumption Survey 1955, Report No. 16. 55 pp.

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Consumer and Food Economics Research Division. 1961. Data on high and average food consumption per person. Radiological Health. 2(3): 119-122.

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Consumer and Food Economics Research Division. 1961. Nutrients available for consumption per capita per day, 1909-1960. Supplement for 1960 to Agriculture Handbook 62, "Consumption of food in the U. S." pp. 43-44.

Consumer and Food Economics Research Division. 1961. Nutrients available for consumption per capita per day 1935-39 and 1947-49. Averages, 1959, 1960, and preliminary estimates for 1961. Table 4. National Food Situation, November. p. 20.

Food Management Practices

Adelson, S. F., Asp, E., and Noble, I. 1961. Household records of foods used and discarded--a pilot study in St. Paul. Journal Amer. Dietet. Assn. 39(6): 578-584.

Development of Food Budgets and Other Basic Data for Food and Nutrition Programs

Consumer and Food Economics Research Division. Estimated cost of one week's food. In Family Economics Review, ARS 62-5. (USDA average issued quarterly, estimated for four regions issued annually.)

Consumer and Food Economics Research Division. 1960. Food and your weight. Home and Garden Bulletin 74. 30 pp.

Consumer and Food Economics Research Division. 1962. Proc. of Nutrition Education Conference, Jan. 29-31, 1962. Miscellaneous Publication 913. (In press)

Nutrition Committee News (periodical, 6 issues): July-Aug. 1961, Sept.-Oct. 1961, Nov.-Dec. 1961, Jan.-Feb. 1962, March-April 1962, May-June 1962.

